US010803420B2

(12) **United States Patent**
Jarvis et al.

(10) **Patent No.: US 10,803,420 B2**
(45) **Date of Patent: Oct. 13, 2020**

(54) **HYBRID MODULAR STORAGE FETCHING SYSTEM**

(71) Applicant: **Staples, Inc.**, Framingham, MA (US)

(72) Inventors: **Daniel Jarvis**, Orlando, FL (US); **Paolo Gerli Amador**, Framingham, MA (US); **Michael Bhaskaran**, Seattle, WA (US); **Vikranth Gopalakrishnan**, Hoboken, NJ (US); **Rodney Gallaway**, Little Rock, AR (US)

(73) Assignee: **Staples, Inc.**, Framingham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 87 days.

(21) Appl. No.: **15/721,472**

(22) Filed: **Sep. 29, 2017**

(65) **Prior Publication Data**

US 2018/0096299 A1 Apr. 5, 2018

Related U.S. Application Data

(60) Provisional application No. 62/403,001, filed on Sep. 30, 2016.

(51) **Int. Cl.**
G06Q 10/08 (2012.01)
G01C 21/20 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06Q 10/0875*** (2013.01); ***G01C 21/206*** (2013.01); ***G05D 1/0225*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G06Q 10/0875; G06Q 10/087; G05D 1/0297; G05D 1/0274; G05D 1/0285;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,450,276 A 6/1969 Ferrari
3,474,877 A 10/1969 Wesener
(Continued)

FOREIGN PATENT DOCUMENTS

CA 1196712 A 11/1985
CA 1210367 A 8/1986
(Continued)

OTHER PUBLICATIONS

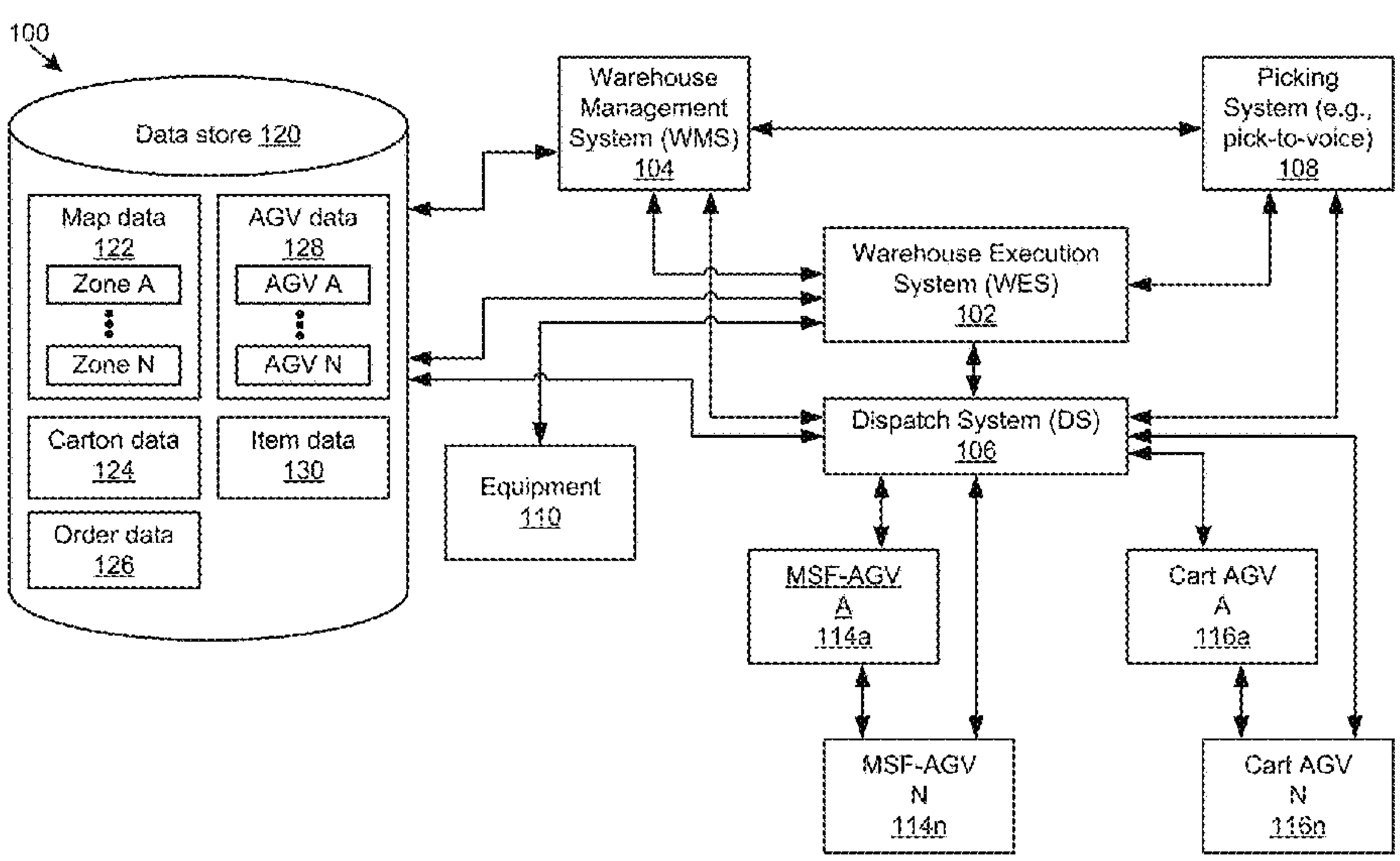
US 9,342,073 B2, 05/2016, Bernstein et al. (withdrawn)
(Continued)

Primary Examiner — Michael V Kerrigan
(74) *Attorney, Agent, or Firm* — Patent Law Works, LLP

(57) **ABSTRACT**

A hybrid modular storage fetching system is described. In an example implementation, the system may include a warehouse execution system adapted to generate a picking schedule for picking pick-to-cart and high-density storage items, and an AGV dispatching system adapted to dispatch a cart automated guided vehicle and a modular storage fetching automated guided vehicle based on the picking schedule. The cart automated guided vehicle may be adapted autonomously transport a carton through a pick-to-cart area and to a pick-cell station. The modular storage fetching automated guided vehicle may be adapted to synchronously autonomously transport a modular storage unit containing items to be placed in the cartons from a high-density storage area to the pick-cell station.

20 Claims, 17 Drawing Sheets



(51) **Int. Cl.**
G05D 1/02 (2020.01)
B65G 43/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G05D 1/0274*** (2013.01); ***G05D 1/0285*** (2013.01); ***G05D 1/0297*** (2013.01); *B65G 43/00* (2013.01); *B65G 2209/06* (2013.01); *G05D 2201/0216* (2013.01)

(58) **Field of Classification Search**
CPC G05D 1/0225; G05D 2201/0216; G05D 1/0088; G01C 21/206; B65G 2209/06; B65G 43/00; B65G 1/1373; B65G 1/137; B65G 1/1378
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,563,327 A 2/1971 Mier
3,628,624 A 12/1971 Wesener
3,970,840 A 7/1976 De Bruine
4,010,409 A 3/1977 Waites
4,077,535 A 3/1978 Oriol
4,215,759 A 8/1980 Diaz
4,258,813 A 3/1981 Rubel
4,278,142 A 7/1981 Kono
4,465,155 A 8/1984 Collins
4,496,274 A 1/1985 Pipes
4,524,314 A 6/1985 Walker
4,530,056 A 7/1985 MacKinnon et al.
4,556,940 A 12/1985 Katoo et al.
4,562,635 A 1/1986 Carter
4,566,032 A 1/1986 Hirooka et al.
4,593,238 A 6/1986 Yamamoto
4,593,239 A 6/1986 Yamamoto
4,652,803 A 3/1987 Kamejima et al.
4,653,002 A 3/1987 Barry
4,657,463 A 4/1987 Pipes
4,678,390 A 7/1987 Bonneton et al.
4,700,302 A 10/1987 Arakawa et al.
4,711,316 A 12/1987 Katou et al.
4,714,399 A 12/1987 Olson
4,716,530 A 12/1987 Ogawa et al.
4,727,492 A 2/1988 Reeve et al.
4,742,283 A 5/1988 Bolger et al.
4,751,983 A 6/1988 Leskovec et al.
4,764,078 A 8/1988 Neri
4,772,832 A 9/1988 Okazaki
4,773,018 A 9/1988 Lundstroem
4,777,601 A 10/1988 Boegli
4,780,817 A 10/1988 Lofgren
4,790,402 A 12/1988 Kasper
4,802,096 A 1/1989 Hainsworth
4,811,227 A 3/1989 Wikstroem
4,811,229 A 3/1989 Wilson
4,817,000 A 3/1989 Eberhardt
4,846,297 A 7/1989 Kasper
4,847,769 A 7/1989 Reeve
4,847,773 A 7/1989 Peteri
4,847,774 A 7/1989 Tomikawa
4,852,677 A 8/1989 Okazaki
4,857,912 A 8/1989 Gilbreath
4,858,132 A 8/1989 Holmquist
4,862,047 A 8/1989 Hosoi
4,863,335 A 9/1989 Herigstad
4,875,172 A 10/1989 Kanayama
4,890,233 A 12/1989 Hosoi
4,918,607 A 4/1990 Wible
4,924,153 A 5/1990 Toru
4,926,544 A 5/1990 Takao
4,935,871 A 6/1990 Grohsmeyer
4,939,650 A 7/1990 Nishikawa
4,939,651 A 7/1990 Onishi
4,942,531 A 7/1990 Hainsworth
4,947,324 A 8/1990 Kamimura
4,950,118 A 8/1990 Mueller
4,954,962 A 9/1990 Weiman
4,982,329 A 1/1991 Onishi
4,990,841 A 2/1991 Elder
4,993,507 A 2/1991 Ohkura
4,994,970 A 2/1991 Noji
4,996,468 A 2/1991 Kasper
5,000,279 A 3/1991 Yamauchi
5,002,145 A 3/1991 Tsukagoshi
5,005,128 A 4/1991 Roberts
5,006,988 A 4/1991 Koren
5,020,620 A 6/1991 Field
5,023,790 A 6/1991 Luke, Jr.
5,040,116 A 8/1991 Weiman
5,052,882 A 10/1991 Harding
5,053,969 A 10/1991 Booth
5,073,749 A 12/1991 Kanayama
5,109,940 A 5/1992 Yardley
5,111,401 A 5/1992 Everett, Jr.
5,125,783 A 6/1992 Kawasoe
5,134,353 A 7/1992 Kita et al.
5,138,560 A 8/1992 Kugler
5,154,249 A 10/1992 Yardley
5,164,648 A 11/1992 Kita et al.
5,170,351 A 12/1992 Nemoto
5,170,352 A 12/1992 Sharma
5,179,329 A 1/1993 Onishi
5,187,664 A 2/1993 Whatcott
5,191,528 A 3/1993 Whatcott
5,192,903 A 3/1993 Kita et al.
5,199,524 A 4/1993 Ivancic
5,202,832 A 4/1993 Lisy
5,211,523 A 5/1993 Andrada Galan
5,216,605 A 6/1993 Whatcott
5,239,249 A 8/1993 Ono
5,249,157 A 9/1993 Taylor
5,281,901 A 1/1994 Yardley
5,305,217 A 4/1994 Kita
5,341,130 A 8/1994 Yardley
5,387,853 A 2/1995 Ono
5,488,277 A 1/1996 Onishi
5,505,473 A 4/1996 Radcliffe
5,510,984 A 4/1996 Markin
5,525,884 A 6/1996 Ike
5,545,960 A 8/1996 Ishikawa
5,548,512 A 8/1996 Quraishi
5,564,890 A 10/1996 Knudsen, Jr.
5,568,030 A 10/1996 Onishi
5,650,703 A 7/1997 Forman
5,669,748 A 9/1997 Knudsen, Jr.
5,875,408 A 2/1999 Bendett
5,877,962 A 3/1999 Radcliffe
5,911,767 A 6/1999 Ilic
5,923,270 A 7/1999 Rintanen
5,961,559 A 10/1999 Moriyama
6,049,745 A 4/2000 Douglas
6,058,339 A 5/2000 Wakisaka
6,092,010 A 7/2000 Drenth
6,246,930 B1 6/2001 Hori
6,256,560 B1 7/2001 Kim
6,345,217 B1 2/2002 Zeitler et al.
6,370,452 B1 4/2002 Pfister
6,377,888 B1 4/2002 Olch
6,459,966 B2 10/2002 Nakano
6,477,463 B2 11/2002 Hamilton
6,481,521 B2 11/2002 Ooishi
6,493,614 B1 12/2002 Jung
6,602,037 B2 8/2003 Winkler
6,615,108 B1 9/2003 Peleg
6,629,028 B2 9/2003 Paromtchik
6,654,647 B1 11/2003 Kal
6,694,216 B1 2/2004 Fujiki
6,721,638 B2 4/2004 Zeitler
6,748,292 B2 6/2004 Mountz
6,772,062 B2 8/2004 Lasky
6,882,910 B2 4/2005 Jeong
6,885,912 B2 4/2005 Peleg
6,895,301 B2 5/2005 Mountz
6,904,343 B2 6/2005 Kang

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,950,722 B2 9/2005 Mountz
6,971,464 B2 12/2005 Marino
7,050,891 B2 5/2006 Chen
7,110,855 B2 9/2006 Leishman
7,155,309 B2 12/2006 Peleg
7,305,287 B2 12/2007 Park
7,333,631 B2 2/2008 Park
7,349,759 B2 3/2008 Peleg
7,402,018 B2 7/2008 Amsbury
7,403,120 B2 7/2008 Bridgelall
7,437,226 B2 10/2008 Shim
7,460,016 B2 12/2008 Clott
7,500,448 B1 3/2009 Melhorn
7,505,849 B2 3/2009 Saarikivi
7,548,166 B2 6/2009 Clott
7,557,714 B2 7/2009 Clott
7,599,777 B2 10/2009 Passeri
7,609,175 B2 10/2009 Bonnefoy
7,613,617 B2 11/2009 McElroy
7,616,127 B2 11/2009 Clott
7,634,332 B2 12/2009 McElroy
7,639,142 B2 12/2009 Clott
7,648,329 B2 1/2010 Stevenson
7,656,296 B2 2/2010 Runyon
7,681,796 B2 3/2010 Zimmerman
7,689,001 B2 3/2010 Sihn
7,693,757 B2 4/2010 Zimmerman
7,765,027 B2 7/2010 Hong
7,826,919 B2 11/2010 Dingle
7,835,821 B2 11/2010 Kim
7,840,328 B2 11/2010 Baginski
7,845,560 B2 12/2010 Emanuel
7,850,413 B2 12/2010 Fontana
7,871,234 B2 1/2011 Yuyama
7,873,469 B2 1/2011 D Andrea
7,890,228 B2 2/2011 Werner
7,894,932 B2 2/2011 Mountz
7,894,933 B2 2/2011 Mountz
7,894,939 B2 2/2011 Allen
7,894,951 B2 2/2011 Norris
7,912,574 B2 3/2011 D Andrea
7,912,633 B1 3/2011 Kennedy
7,920,962 B2 4/2011 D Andrea
7,925,514 B2 4/2011 McElroy
7,953,551 B2 5/2011 Park
7,980,808 B2 7/2011 Chilson
7,991,521 B2 8/2011 Stewart
7,996,109 B2 8/2011 Allen
8,010,230 B2 8/2011 Allen
8,020,657 B2 9/2011 Catalfano
8,031,086 B2 10/2011 Dickson
8,068,978 B2 11/2011 D Andrea
8,072,309 B2 12/2011 Duckworth
8,075,243 B2 12/2011 Stevenson
8,146,702 B2 4/2012 Emond
8,160,728 B2 4/2012 Curtis
8,170,711 B2 5/2012 Dingle
8,192,137 B2 6/2012 Chilson
8,193,903 B2 6/2012 Duckworth
8,196,835 B2 6/2012 Emanuel
8,200,423 B2 6/2012 Kennedy
8,204,624 B2 6/2012 Allen
8,210,791 B2 7/2012 Chilson
8,220,710 B2 7/2012 D Andrea
8,229,619 B2 7/2012 Shim
8,239,291 B2 8/2012 Verminski
8,265,873 B2 9/2012 D Andrea
8,269,643 B2 9/2012 Chou
8,271,132 B2 9/2012 Walton
8,280,546 B2 10/2012 Dingle
8,280,547 B2 10/2012 Dingle
8,311,902 B2 11/2012 Mountz
8,369,981 B2 2/2013 Spaulding
8,381,982 B2 2/2013 Emanuel
8,406,949 B2 3/2013 Kondo
8,412,400 B2 4/2013 D Andrea
8,417,444 B2 4/2013 Smid
8,418,919 B1 4/2013 Beyda
8,425,173 B2 4/2013 Lert
8,433,442 B2 4/2013 Friedman
8,433,469 B2 4/2013 Day
8,444,369 B2 5/2013 Bragg
8,452,464 B2 5/2013 Schloemer
8,457,978 B2 6/2013 McElroy
8,473,140 B2 6/2013 Norris
8,483,869 B2 7/2013 Wurman
8,498,734 B2 7/2013 Dunsker
8,515,612 B2 8/2013 Shitamoto
8,538,692 B2 9/2013 D Andrea
8,571,781 B2 10/2013 Bernstein
8,577,551 B2 11/2013 Corbett
8,587,455 B2 11/2013 Porte
8,594,834 B1 11/2013 Clark et al.
8,594,835 B2 11/2013 Toebes
8,606,392 B2 12/2013 D Andrea
8,626,332 B2 1/2014 Dunsker
8,626,335 B2 1/2014 Barbehenn
8,639,382 B1 1/2014 Clark
8,649,899 B2 2/2014 Wurman
8,653,945 B2 2/2014 Lee
8,670,892 B2 3/2014 Yang
8,676,426 B1 3/2014 Murphy
8,700,502 B2 4/2014 Mountz
8,718,814 B1 5/2014 Clark
8,718,815 B2 5/2014 Shimamura
8,725,286 B2 5/2014 Dingle
8,725,317 B2 5/2014 Elston
8,725,362 B2 5/2014 Jensen
8,725,363 B2 5/2014 Jensen
8,731,777 B2 5/2014 Schloemer
8,740,538 B2 6/2014 Lert
8,751,063 B2 6/2014 Wilson
8,751,147 B2 6/2014 Colwell
8,755,936 B2 6/2014 Friedman
8,760,276 B2 6/2014 Yamazato
8,761,989 B1 6/2014 Murphy
8,788,121 B2 7/2014 Klinger
8,798,784 B1 8/2014 Clark
8,798,786 B2 8/2014 Chaitin Pollak
8,798,840 B2 8/2014 Fong
8,805,573 B2 8/2014 Brunner
8,805,574 B2 8/2014 Watt
8,825,257 B2 9/2014 Ozaki
8,825,367 B2 9/2014 Nagasawa
8,831,984 B2 9/2014 Santini
8,862,397 B2 10/2014 Kubota
8,874,300 B2 10/2014 Catalfano
8,874,360 B2 10/2014 Davis
8,880,416 B2 11/2014 McElroy
8,886,385 B2 11/2014 Moriguchi
8,892,240 B1 11/2014 Vliet et al.
8,892,241 B2 11/2014 Weiss
8,909,368 B2 12/2014 D Andrea
8,930,133 B2 1/2015 Barbehenn
8,948,956 B2 2/2015 Takahashi
8,954,188 B2 2/2015 Sullivan et al.
8,965,561 B2 2/2015 Jacobus
8,965,562 B1 2/2015 Wurman
8,965,578 B2 2/2015 Linda
8,970,363 B2 3/2015 Schumacher
8,972,045 B1 3/2015 Wurman
8,983,647 B1 3/2015 Casteel
8,988,285 B2 3/2015 Smid
8,989,918 B2 3/2015 Sturm
9,002,506 B1 4/2015 Shareef
9,002,581 B2 4/2015 Wellman
9,008,827 B1 4/2015 Casteel
9,008,828 B2 4/2015 Worsley
9,008,829 B2 4/2015 Worsley
9,008,830 B2 4/2015 Worsley
9,009,072 B2 4/2015 Durham
9,014,902 B1 4/2015 Murphy
9,020,679 B2 4/2015 Allen
9,026,301 B2 5/2015 Allen

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,043,016 B2 5/2015 Schmaltz
9,046,893 B2 6/2015 Douglas
9,051,120 B2 6/2015 Toebes
9,052,714 B2 6/2015 Creasey
9,056,719 B2 6/2015 Tanahashi
9,067,317 B1 6/2015 Wurman
9,073,736 B1 7/2015 Goyal
9,082,293 B2 7/2015 Wellman
9,087,314 B2 7/2015 D Andrea
9,090,214 B2 7/2015 Wilson
9,090,400 B2 7/2015 Barbehenn
9,096,375 B2 8/2015 Lert et al.
9,098,080 B2 8/2015 Norris et al.
9,110,464 B2 8/2015 Holland et al.
9,111,251 B1 * 8/2015 Brazeau G06Q 10/087
9,114,838 B2 8/2015 Bernstein et al.
9,120,621 B1 9/2015 Curlander et al.
9,120,622 B1 9/2015 Elazary et al.
9,122,276 B2 9/2015 Kraimer et al.
9,129,250 B1 9/2015 Sestini et al.
9,134,734 B2 9/2015 Lipkowski et al.
9,146,559 B2 9/2015 Kuss et al.
9,147,173 B2 9/2015 Jones et al.
9,150,263 B2 10/2015 Bernstein et al.
9,152,149 B1 10/2015 Palamarchuk et al.
9,185,998 B1 11/2015 Dwarakanath et al.
9,188,982 B2 11/2015 Thomson
9,193,404 B2 11/2015 Bernstein et al.
9,202,382 B2 12/2015 Klinger et al.
9,206,023 B2 12/2015 Wong et al.
9,207,673 B2 12/2015 Pulskamp et al.
9,207,676 B2 12/2015 Wu et al.
9,211,920 B1 12/2015 Bernstein et al.
9,213,934 B1 12/2015 Versteeg et al.
9,216,745 B2 12/2015 Beardsley et al.
9,218,003 B2 12/2015 Fong et al.
9,218,316 B2 12/2015 Bemstein et al.
9,242,799 B1 1/2016 O'Brien et al.
9,244,463 B2 1/2016 Pfaff et al.
9,248,973 B1 2/2016 Brazeau
9,260,244 B1 2/2016 Cohn
9,266,236 B2 2/2016 Clark et al.
9,268,334 B1 2/2016 Vavrick
9,274,526 B2 3/2016 Murai et al.
9,280,153 B1 3/2016 Palamarchuk et al.
9,280,157 B2 3/2016 Wurman et al.
9,286,590 B2 3/2016 Segawa et al.
9,290,220 B2 3/2016 Bernstein et al.
9,304,001 B2 4/2016 Park et al.
9,310,802 B1 4/2016 Elkins et al.
9,317,034 B2 4/2016 Hoffman et al.
9,329,078 B1 5/2016 Mundhenke et al.
9,329,599 B1 5/2016 Sun et al.
9,330,373 B2 5/2016 Mountz et al.
9,341,720 B2 5/2016 Garin et al.
9,342,811 B2 5/2016 Mountz et al.
9,346,619 B1 5/2016 O'Brien et al.
9,346,620 B2 5/2016 Brunner et al.
9,352,745 B1 5/2016 Theobald
9,355,065 B2 5/2016 Donahue
9,365,348 B1 6/2016 Agarwal et al.
9,367,827 B1 6/2016 Lively et al.
9,367,831 B1 6/2016 Besehanic
9,371,184 B1 6/2016 Dingle et al.
9,378,482 B1 6/2016 Pikler et al.
9,389,609 B1 7/2016 Mountz et al.
9,389,612 B2 7/2016 Bernstein et al.
9,389,614 B2 7/2016 Shani
9,394,016 B2 7/2016 Bernstein et al.
9,395,725 B2 7/2016 Bernstein et al.
9,404,756 B2 8/2016 Fong et al.
9,405,016 B2 8/2016 Yim
9,427,874 B1 8/2016 Rublee
9,429,940 B2 8/2016 Bernstein et al.
9,429,944 B2 8/2016 Filippov et al.
9,436,184 B2 9/2016 D'Andrea et al.
9,440,790 B2 9/2016 Mountz et al.
9,448,560 B2 9/2016 D'Andrea et al.
9,451,020 B2 9/2016 Liu et al.
9,452,883 B1 9/2016 Wurman et al.
9,457,730 B2 10/2016 Bernstein et al.
9,463,927 B1 10/2016 Theobald
9,469,477 B1 10/2016 Palamarchuk et al.
9,471,894 B2 10/2016 Palamarchuk et al.
9,481,410 B2 11/2016 Bernstein et al.
9,493,184 B2 11/2016 Castaneda et al.
9,493,303 B2 11/2016 Wurman et al.
9,495,656 B2 11/2016 Adler et al.
9,501,756 B2 11/2016 Stevens et al.
9,511,934 B2 12/2016 Wurman et al.
9,517,899 B2 12/2016 Watt et al.
9,519,284 B2 12/2016 Wurman et al.
9,519,880 B1 12/2016 Cohn
9,522,817 B2 12/2016 Castaneda et al.
9,523,582 B2 12/2016 Chandrasekar et al.
9,527,710 B1 12/2016 Hussain et al.
9,533,828 B1 1/2017 Dwarakanath et al.
9,536,767 B1 1/2017 Adler et al.
9,540,171 B2 1/2017 Elazary et al.
9,547,945 B2 1/2017 McCabe et al.
9,551,987 B1 1/2017 Mountz et al.
9,563,206 B2 2/2017 Zini et al.
9,568,917 B2 2/2017 Jones et al.
9,582,783 B2 2/2017 Mountz et al.
9,592,961 B2 3/2017 Weiss
9,645,968 B2 5/2017 Elston et al.
9,663,295 B1 5/2017 Wurman et al.
9,663,296 B1 5/2017 Dingle et al.
9,676,552 B2 6/2017 Agarwal et al.
9,679,270 B2 6/2017 Zini et al.
9,694,975 B2 7/2017 Lert et al.
9,694,976 B1 7/2017 Wurman et al.
9,725,239 B2 8/2017 Lert et al.
9,731,896 B2 8/2017 Elazary et al.
9,738,449 B1 8/2017 Palamarchuk et al.
9,740,212 B2 8/2017 D'Andrea et al.
9,766,620 B2 9/2017 Bernstein et al.
9,771,217 B2 9/2017 Lert et al.
9,783,364 B2 10/2017 Worsley
9,785,152 B2 10/2017 Chandrasekar et al.
9,792,577 B2 10/2017 Mountz et al.
9,802,762 B1 10/2017 Pikler et al.
9,836,046 B2 12/2017 Wilson et al.
9,841,758 B2 12/2017 Bernstein et al.
9,856,084 B1 1/2018 Palamarchuk et al.
9,873,561 B2 1/2018 Agarwal et al.
2001/0018637 A1 8/2001 Hamilton
2001/0027360 A1 10/2001 Nakano
2002/0021954 A1 2/2002 Winkler
2002/0027652 A1 3/2002 Paromtchik et al.
2002/0074172 A1 6/2002 Sugiyama et al.
2002/0165648 A1 11/2002 Zeitler
2003/0046021 A1 3/2003 Lasky et al.
2003/0106731 A1 6/2003 Marino et al.
2003/0208304 A1 11/2003 Peless et al.
2004/0006415 A1 1/2004 Kang
2004/0006416 A1 1/2004 Jeong
2004/0010337 A1 1/2004 Mountz
2004/0010339 A1 1/2004 Mountz
2004/0024489 A1 2/2004 Fujiki et al.
2004/0062419 A1 4/2004 Roh et al.
2004/0093116 A1 5/2004 Mountz
2004/0243278 A1 12/2004 Leishman
2005/0065655 A1 3/2005 Hong et al.
2005/0080524 A1 4/2005 Park
2005/0113990 A1 5/2005 Peless et al.
2005/0222722 A1 10/2005 Chen
2005/0228555 A1 10/2005 Roh et al.
2005/0244259 A1 11/2005 Chilson et al.
2006/0071790 A1 4/2006 Duron
2006/0149465 A1 7/2006 Park et al.
2006/0184013 A1 8/2006 Emanuel et al.
2006/0210382 A1 9/2006 Mountz et al.
2006/0245893 A1 11/2006 Schottke

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0255948 A1 11/2006 Runyon et al.
2006/0255949 A1 11/2006 Roeder et al.
2006/0255950 A1 11/2006 Roeder et al.
2006/0255951 A1 11/2006 Roeder et al.
2006/0255954 A1 11/2006 Sorenson, Jr. et al.
2006/0271274 A1 11/2006 Saarikivi
2006/0280585 A1 12/2006 Passeri et al.
2007/0017984 A1 1/2007 Mountz et al.
2007/0021863 A1 1/2007 Mountz et al.
2007/0021864 A1 1/2007 Mountz et al.
2007/0096922 A1 5/2007 Sorenson, Jr. et al.
2007/0112461 A1 5/2007 Zini et al.
2007/0112463 A1 5/2007 Roh et al.
2007/0123308 A1 5/2007 Kim et al.
2007/0129849 A1 6/2007 Zini et al.
2007/0136152 A1 6/2007 Dunsker et al.
2007/0150109 A1 6/2007 Peless et al.
2007/0152057 A1 7/2007 Cato et al.
2007/0152845 A1 7/2007 Porte et al.
2007/0179690 A1 8/2007 Stewart
2007/0193798 A1 8/2007 Allard et al.
2007/0198144 A1 8/2007 Norris et al.
2007/0198145 A1 8/2007 Norris et al.
2007/0198174 A1 8/2007 Williams et al.
2007/0198175 A1 8/2007 Williams et al.
2007/0198282 A1 8/2007 Williams et al.
2007/0208477 A1 9/2007 Baginski et al.
2007/0219666 A1 9/2007 Filippov et al.
2007/0269299 A1 11/2007 Ross et al.
2007/0288123 A1 12/2007 D'Andrea et al.
2007/0290040 A1 12/2007 Wurman et al.
2007/0293978 A1 12/2007 Wurman et al.
2007/0294029 A1 12/2007 D'Andrea et al.
2007/0297879 A1 12/2007 Yuyama et al.
2008/0001372 A1 1/2008 Hoffman et al.
2008/0051984 A1 2/2008 Wurman et al.
2008/0051985 A1 2/2008 D'Andrea et al.
2008/0071429 A1 3/2008 Kraimer et al.
2008/0077511 A1 3/2008 Zimmerman
2008/0129445 A1 6/2008 Kraimer et al.
2008/0157972 A1 7/2008 Duron et al.
2008/0166217 A1 7/2008 Fontana
2008/0167753 A1 7/2008 Peless et al.
2008/0167884 A1 7/2008 Mountz et al.
2008/0167933 A1 7/2008 Hoffman et al.
2008/0189005 A1 8/2008 Chilson et al.
2008/0199298 A1 8/2008 Chilson et al.
2009/0099716 A1 4/2009 Roh et al.
2009/0138151 A1 5/2009 Smid et al.
2009/0185884 A1 7/2009 Wurman et al.
2009/0198376 A1 8/2009 Friedman et al.
2009/0198381 A1 8/2009 Friedman et al.
2009/0234499 A1 9/2009 Nielsen et al.
2010/0039293 A1 2/2010 Porte et al.
2010/0114405 A1 5/2010 Elston et al.
2010/0127883 A1 5/2010 Chou
2010/0138095 A1 6/2010 Redmann, Jr. et al.
2010/0141483 A1 6/2010 Thacher et al.
2010/0145551 A1 6/2010 Pulskamp et al.
2010/0234990 A1 9/2010 Zini et al.
2010/0234991 A1 9/2010 Zini et al.
2010/0266381 A1 10/2010 Chilson et al.
2010/0300841 A1 12/2010 O'Brien
2010/0316468 A1 12/2010 Lert et al.
2010/0316469 A1 12/2010 Lert et al.
2010/0316470 A1 12/2010 Lert et al.
2010/0322746 A1 12/2010 Lert et al.
2010/0322747 A1 12/2010 Lert et al.
2011/0010023 A1 1/2011 Kunzig et al.
2011/0015779 A1 1/2011 D'Andrea et al.
2011/0046813 A1 2/2011 Castaneda et al.
2011/0056760 A1 3/2011 Schendel et al.
2011/0060449 A1 3/2011 Wurman et al.
2011/0066284 A1 3/2011 Curtis
2011/0071718 A1 3/2011 Norris et al.
2011/0103924 A1 5/2011 Watt et al.
2011/0112758 A1 5/2011 D'Andrea et al.
2011/0118903 A1 5/2011 Kraimer et al.
2011/0121068 A1 5/2011 Emanuel et al.
2011/0125312 A1 5/2011 D'Andrea et al.
2011/0130866 A1 6/2011 D'Andrea et al.
2011/0130954 A1 6/2011 D'Andrea et al.
2011/0137457 A1 6/2011 Zini et al.
2011/0153063 A1 6/2011 Wurman et al.
2011/0160949 A1 6/2011 Kondo
2011/0163160 A1 7/2011 Zini et al.
2011/0166721 A1 7/2011 Castaneda et al.
2011/0166737 A1 7/2011 Tanaka et al.
2011/0191135 A1 8/2011 Williams et al.
2011/0208745 A1 8/2011 Dietsch et al.
2011/0270438 A1 11/2011 Shimamura
2012/0038455 A1 2/2012 Kraimer et al.
2012/0041677 A1 2/2012 D'Andrea et al.
2012/0046820 A1 2/2012 Allard et al.
2012/0078471 A1 3/2012 Siefring et al.
2012/0139715 A1 6/2012 Yamazato
2012/0143427 A1 6/2012 Hoffman et al.
2012/0168240 A1 7/2012 Wilson et al.
2012/0168241 A1 7/2012 Bernstein et al.
2012/0173047 A1 7/2012 Bernstein et al.
2012/0173048 A1 7/2012 Bernstein et al.
2012/0173049 A1 7/2012 Bernstein et al.
2012/0173050 A1 7/2012 Bernstein et al.
2012/0176222 A1 7/2012 Baek et al.
2012/0176491 A1 7/2012 Garin et al.
2012/0197477 A1 8/2012 Colwell
2012/0232739 A1 9/2012 Takahashi et al.
2012/0239191 A1 9/2012 Versteeg et al.
2012/0239224 A1 9/2012 McCabe et al.
2012/0239238 A1 9/2012 Harvey et al.
2012/0255810 A1 10/2012 Yang
2012/0282070 A1 11/2012 D'Andrea et al.
2012/0321423 A1 12/2012 MacKnight et al.
2012/0323746 A1 12/2012 Mountz et al.
2012/0330458 A1 12/2012 Weiss
2012/0330492 A1 12/2012 Douglas et al.
2013/0006442 A1 1/2013 Williams et al.
2013/0054005 A1 2/2013 Stevens et al.
2013/0058743 A1 3/2013 Rebstock
2013/0103185 A1 4/2013 Wurman et al.
2013/0103552 A1 4/2013 Hoffman et al.
2013/0105570 A1 5/2013 Dunsker et al.
2013/0110279 A1 5/2013 Dunsker et al.
2013/0110281 A1 5/2013 Jones et al.
2013/0124013 A1 5/2013 Elston et al.
2013/0124014 A1 5/2013 Elston et al.
2013/0131895 A1 5/2013 Elston et al.
2013/0131910 A1 5/2013 Takahashi et al.
2013/0158773 A1 6/2013 Wu et al.
2013/0166108 A1 6/2013 Sturm
2013/0173049 A1 7/2013 Brunner et al.
2013/0173089 A1 7/2013 Bernstein et al.
2013/0190963 A1 7/2013 Kuss et al.
2013/0197720 A1 8/2013 Kraimer et al.
2013/0197760 A1 8/2013 Castaneda et al.
2013/0204429 A1 8/2013 D'Andrea et al.
2013/0204480 A1 8/2013 D'Andrea et al.
2013/0211626 A1 8/2013 Nagasawa
2013/0238170 A1 9/2013 Klinger
2013/0246229 A1 9/2013 Mountz et al.
2013/0251480 A1 9/2013 Watt et al.
2013/0275045 A1 10/2013 Tsujimoto et al.
2013/0282222 A1 10/2013 Ozaki et al.
2013/0297151 A1 11/2013 Castaneda et al.
2013/0302132 A1 11/2013 D'Andrea et al.
2013/0304253 A1 11/2013 Wurman et al.
2013/0325243 A1 12/2013 Lipkowski et al.
2013/0338874 A1 12/2013 Donahue
2013/0338885 A1 12/2013 Kirk et al.
2013/0338886 A1 12/2013 Callea et al.
2014/0005933 A1 1/2014 Fong et al.
2014/0020964 A1 1/2014 Bernstein et al.
2014/0032035 A1 1/2014 Thomson
2014/0067184 A1 3/2014 Murphy

(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0072392	A1	3/2014	Tanahashi
2014/0081505	A1	3/2014	Klinger et al.
2014/0088758	A1	3/2014	Lert et al.
2014/0100690	A1	4/2014	Wurman et al.
2014/0100715	A1	4/2014	Mountz et al.
2014/0100998	A1	4/2014	Mountz et al.
2014/0100999	A1	4/2014	Mountz et al.
2014/0107833	A1	4/2014	Segawa et al.
2014/0124462	A1	5/2014	Yamashita
2014/0135977	A1	5/2014	Wurman et al.
2014/0172223	A1	6/2014	Murphy
2014/0188671	A1	7/2014	Mountz et al.
2014/0195040	A1	7/2014	Wurman et al.
2014/0195121	A1	7/2014	Castaneda et al.
2014/0214195	A1	7/2014	Worsley
2014/0214196	A1	7/2014	Worsley
2014/0214234	A1	7/2014	Worsley
2014/0228999	A1	8/2014	D'Andrea et al.
2014/0236393	A1	8/2014	Bernstein et al.
2014/0236413	A1	8/2014	D'Andrea et al.
2014/0238762	A1	8/2014	Berberian et al.
2014/0244097	A1	8/2014	Colwell
2014/0271063	A1	9/2014	Lert et al.
2014/0277691	A1	9/2014	Jacobus et al.
2014/0297093	A1	10/2014	Murai et al.
2014/0303773	A1	10/2014	Wurman et al.
2014/0330425	A1	11/2014	Stevens et al.
2014/0330426	A1	11/2014	Brunner et al.
2014/0343714	A1	11/2014	Clark et al.
2014/0343758	A1	11/2014	Kraimer et al.
2014/0345957	A1	11/2014	Bernstein et al.
2014/0350768	A1	11/2014	Filippov et al.
2014/0350831	A1	11/2014	Hoffman et al.
2014/0371973	A1	12/2014	Pfaff et al.
2015/0012209	A1	1/2015	Park et al.
2015/0019043	A1	1/2015	Creasey et al.
2015/0022400	A1	1/2015	Smid et al.
2015/0025713	A1	1/2015	Klinger et al.
2015/0057843	A1	2/2015	Kraimer et al.
2015/0066283	A1	3/2015	Wurman et al.
2015/0073586	A1	3/2015	Weiss
2015/0073589	A1*	3/2015	Khodl B25J 5/007 700/218
2015/0088302	A1	3/2015	Mountz et al.
2015/0117995	A1	4/2015	D'Andrea et al.
2015/0142168	A1	5/2015	Holland et al.
2015/0151912	A1	6/2015	Mountz et al.
2015/0183581	A1	7/2015	Worsley
2015/0224941	A1	8/2015	Bernstein et al.
2015/0226560	A1	8/2015	Chandrasekar et al.
2015/0226561	A1	8/2015	Chandrasekar et al.
2015/0227862	A1	8/2015	Chandrasekar et al.
2015/0227885	A1	8/2015	Zini et al.
2015/0234386	A1	8/2015	Zini et al.
2015/0261223	A1	9/2015	Fong et al.
2015/0266672	A1	9/2015	Lert et al.
2015/0284010	A1	10/2015	Beardsley et al.
2015/0286218	A1	10/2015	Shani
2015/0301532	A1	10/2015	Norris et al.
2015/0307278	A1	10/2015	Wickham et al.
2015/0344085	A1	12/2015	Bernstein et al.
2015/0355639	A1	12/2015	Versteeg et al.
2015/0362919	A1	12/2015	Bernstein et al.
2015/0370257	A1	12/2015	Bernstein et al.
2015/0371181	A1	12/2015	Palamarchuk et al.
2016/0004253	A1	1/2016	Bernstein et al.
2016/0021178	A1	1/2016	Liu et al.
2016/0033967	A1	2/2016	Bernstein et al.
2016/0033971	A1	2/2016	Thomson
2016/0042314	A1	2/2016	Mountz et al.
2016/0048130	A1	2/2016	Vavrick
2016/0054734	A1	2/2016	Bernstein et al.
2016/0069691	A1	3/2016	Fong
2016/0090133	A1	3/2016	Bernstein et al.
2016/0097862	A1	4/2016	Yim
2016/0101741	A1	4/2016	Bernstein et al.
2016/0101937	A1	4/2016	Adler et al.
2016/0103014	A1	4/2016	Mundhenke et al.
2016/0117936	A1	4/2016	Klinger et al.
2016/0147231	A1	5/2016	Sun et al.
2016/0171441	A1	6/2016	Lively et al.
2016/0176637	A1	6/2016	Ackerman et al.
2016/0185526	A1	6/2016	Lert et al.
2016/0187886	A1	6/2016	Jones et al.
2016/0202696	A1	7/2016	Bernstein et al.
2016/0203543	A1	7/2016	Snow
2016/0232477	A1	8/2016	Cortes et al.
2016/0232490	A1	8/2016	Mountz et al.
2016/0246299	A1	8/2016	Berberian et al.
2016/0264357	A1	9/2016	Agarwal et al.
2016/0282871	A1	9/2016	Bernstein et al.
2016/0291591	A1	10/2016	Bernstein et al.
2016/0304280	A1	10/2016	Elazary et al.
2016/0304281	A1	10/2016	Elazary et al.
2016/0334799	A1	11/2016	D'Andrea et al.
2016/0339587	A1	11/2016	Rublee
2016/0347545	A1	12/2016	Lindbo et al.
2016/0349748	A1	12/2016	Bernstein et al.
2016/0379161	A1	12/2016	Adler et al.
2017/0011336	A1	1/2017	Stevens et al.
2017/0022010	A1	1/2017	D'Andrea et al.
2017/0038770	A1	2/2017	Wurman et al.
2017/0043953	A1*	2/2017	Battles B65G 1/1373
2017/0052033	A1	2/2017	Fong et al.
2017/0057798	A1	3/2017	Dues et al.
2017/0060138	A1	3/2017	Chandrasekar et al.
2017/0080352	A1	3/2017	Bernstein et al.
2017/0174431	A1*	6/2017	Borders B65G 65/00
2017/0183005	A1	6/2017	Elston et al.
2017/0183159	A1	6/2017	Weiss
2017/0269608	A1	9/2017	Chandrasekar et al.
2017/0286908	A1	10/2017	Lively et al.
2017/0313517	A1	11/2017	Agarwal et al.
2017/0362032	A1	12/2017	Sullivan et al.
2018/0016098	A1	1/2018	Lert et al.

FOREIGN PATENT DOCUMENTS

CA	1228142	A	10/1987
CA	1238103	A	6/1988
CA	1264490	A	1/1990
CA	1267866	A	4/1990
CA	1269740	A	5/1990
CA	1271544	A	7/1990
CA	1275721	C	10/1990
CA	1276264	C	11/1990
CA	2029773	A1	5/1991
CA	1291725	C	11/1991
CA	2036104	A1	11/1991
CA	2042133	A1	1/1992
CA	2049578	A1	2/1992
CA	2296837	A1	2/1992
CA	2094833	A1	4/1992
CA	1304043	C	6/1992
CA	2095442	A1	6/1992
CA	1304820	C	7/1992
CA	1323084	C	10/1993
CA	2189853	A1	11/1995
CA	2244668	A1	3/1999
CA	2469652	A1	6/2003
CA	2514523	A1	8/2004
CA	2565553	A1	11/2005
CA	2577346	A1	4/2006
CA	2613180	A1	1/2007
CA	2921584	A1	1/2007
CA	2625885	A1	4/2007
CA	2625895	A1	4/2007
CA	2837477	A1	4/2007
CA	2864027	A1	4/2007
CA	2636233	A1	7/2007
CA	2640769	A1	8/2007
CA	2652114	A1	12/2007
CA	2654258	A1	12/2007
CA	2654260	A1	12/2007

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

CA	2654263	A1	12/2007
CA	2654295	A1	12/2007
CA	2654336	A1	12/2007
CA	2654471	A1	12/2007
CA	2748398	A1	12/2007
CA	2748407	A1	12/2007
CA	2750043	A1	12/2007
CA	2781624	A1	12/2007
CA	2781857	A1	12/2007
CA	2838044	A1	12/2007
CA	2866664	A1	12/2007
CA	2921134	A1	12/2007
CA	2663578	A1	4/2008
CA	2860745	A1	4/2008
CA	2671955	A1	7/2008
CA	2673025	A1	7/2008
CA	2674241	A1	7/2008
CA	2691710	A1	12/2008
CA	2721345	A1	10/2009
CA	2760127	A1	11/2009
CA	2760225	A1	11/2009
CA	2743706	A1	6/2010
CA	2754626	A1	9/2010
CA	2765565	A1	1/2011
CA	2932535	A1	1/2011
CA	2932537	A1	1/2011
CA	2770139	A1	2/2011
CA	2773963	A1	3/2011
CA	2778111	A1	5/2011
CA	2784874	A1	7/2011
CA	2868578	A1	7/2011
CA	2806852	A1	2/2012
CA	2823715	A1	7/2012
CA	2827281	A1	8/2012
CA	2827735	A1	8/2012
CA	2770715	A1	9/2012
CA	2770918	A1	9/2012
CA	2831832	A1	10/2012
CA	2836933	A1	12/2012
CA	2851774	A1	4/2013
CA	2799871	A1	6/2013
CA	2866708	A1	9/2013
CA	2938894	A1	9/2013
CA	2813874	A1	12/2013
CA	2824189	A1	2/2014
CA	2870381	A1	4/2014
CA	2935223	A1	4/2014
CA	2894546	A1	6/2014
CA	2845229	A1	9/2014
CA	2899553	A1	10/2014
CA	2882452	A1	8/2015
CA	2886121	A1	10/2015
WO	2012154872	A2	11/2012
WO	2016015000	A2	1/2016

OTHER PUBLICATIONS

US 9,791,858 B2, 10/2017, Wilson et al. (withdrawn)

"Warehouse Robots at Work", IEEE Spectrum, Jul. 21, 2008. YouTube https://www.youtube.com/watch?v=IWsMdN7HMuA. (see attached PDF screenshots).*

International Search Report and Written Opinion, PCT/US2017/054627, dated Jan. 5, 2018 (15 pages).

International Search Report and Written Opinion, PCT/US2018/012645, dated Mar. 7, 2018 (13 pages).

International Search Report and Written Opinion, PCT/US2018/012641, dated Mar. 7, 2018 (17 pages).

US 7,460,017, 12/2008, (withdrawn)

US 9,050,932, 6/2015, (withdrawn)

* cited by examiner

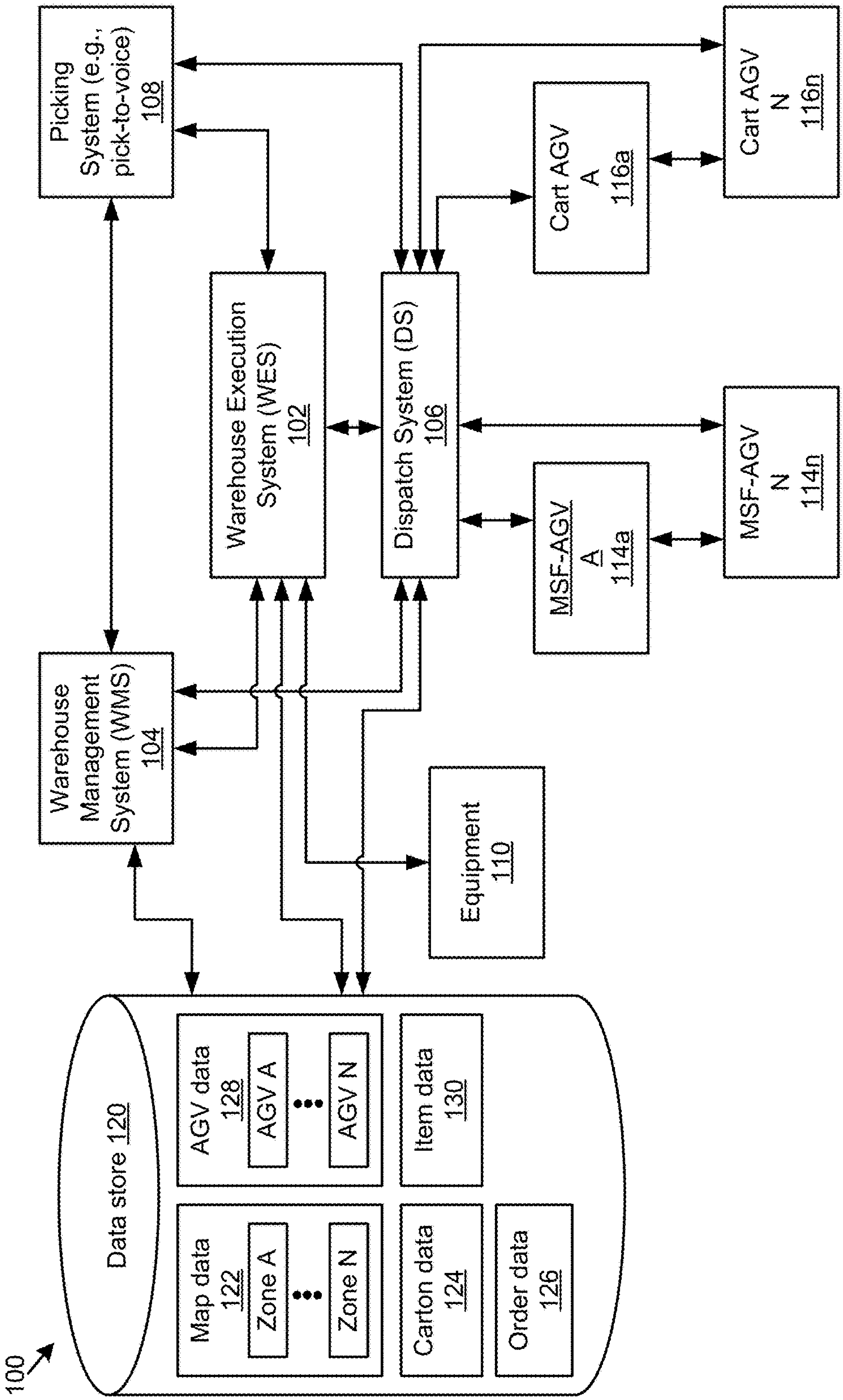

100
Picking System (e.g., pick-to-voice) 108
Warehouse Execution System (WES) 102
Dispatch System (DS) 106
Cart AGV A 116a
Cart AGV N 116n
MSF-AGV A 114a
MSF-AGV N 114n
Warehouse Management System (WMS) 104
Equipment 110
Data store 120
Map data 122
Zone A
Zone N
AGV data 128
AGV A
AGV N
Carton data 124
Item data 130
Order data 126

Figure 1

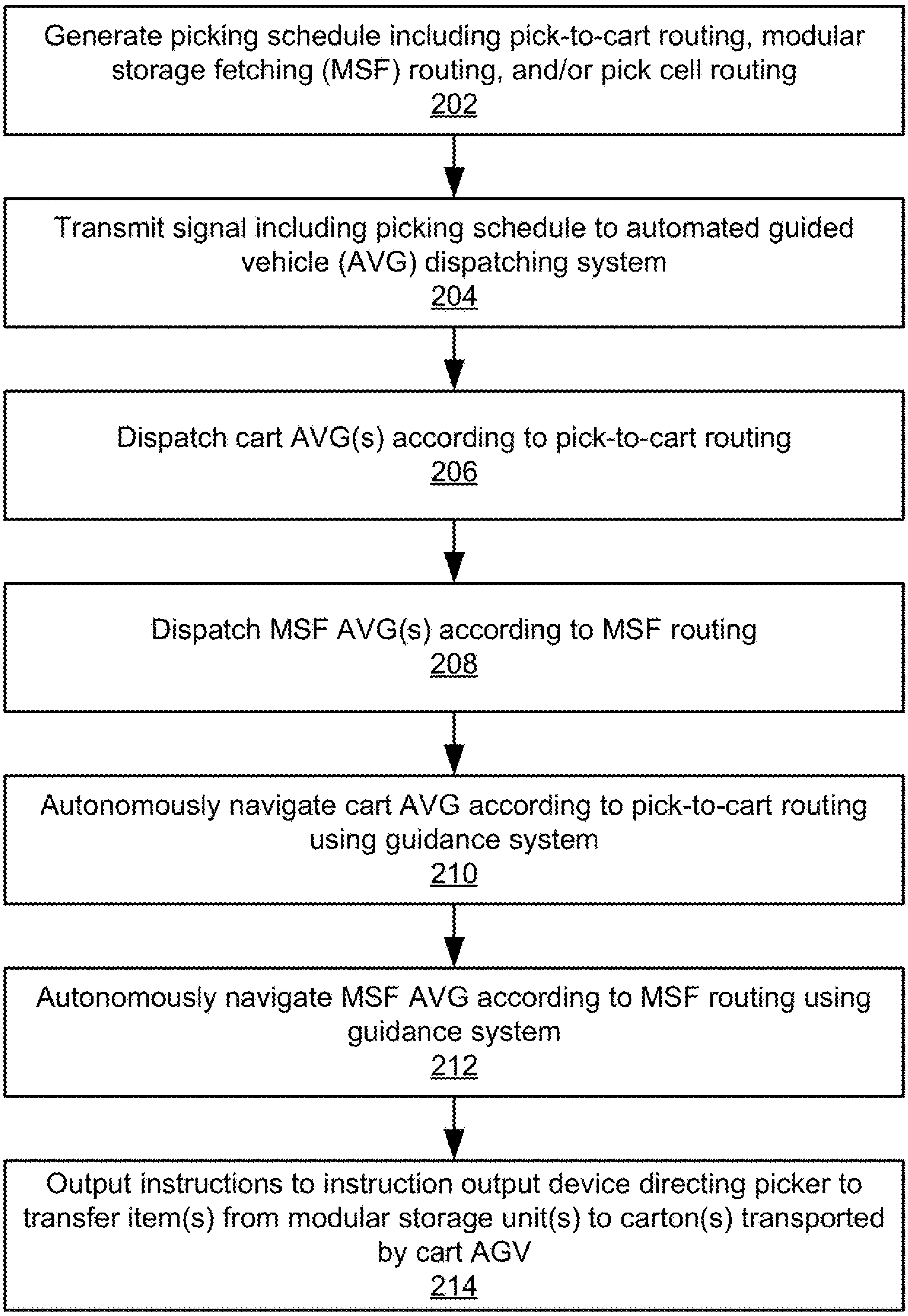

Generate picking schedule including pick-to-cart routing, modular storage fetching (MSF) routing, and/or pick cell routing
202
Transmit signal including picking schedule to automated guided vehicle (AVG) dispatching system
204
Dispatch cart AVG(s) according to pick-to-cart routing
206
Dispatch MSF AVG(s) according to MSF routing
208
Autonomously navigate cart AVG according to pick-to-cart routing using guidance system
210
Autonomously navigate MSF AVG according to MSF routing using guidance system
212
Output instructions to instruction output device directing picker to transfer item(s) from modular storage unit(s) to carton(s) transported by cart AGV
214

Figure 2

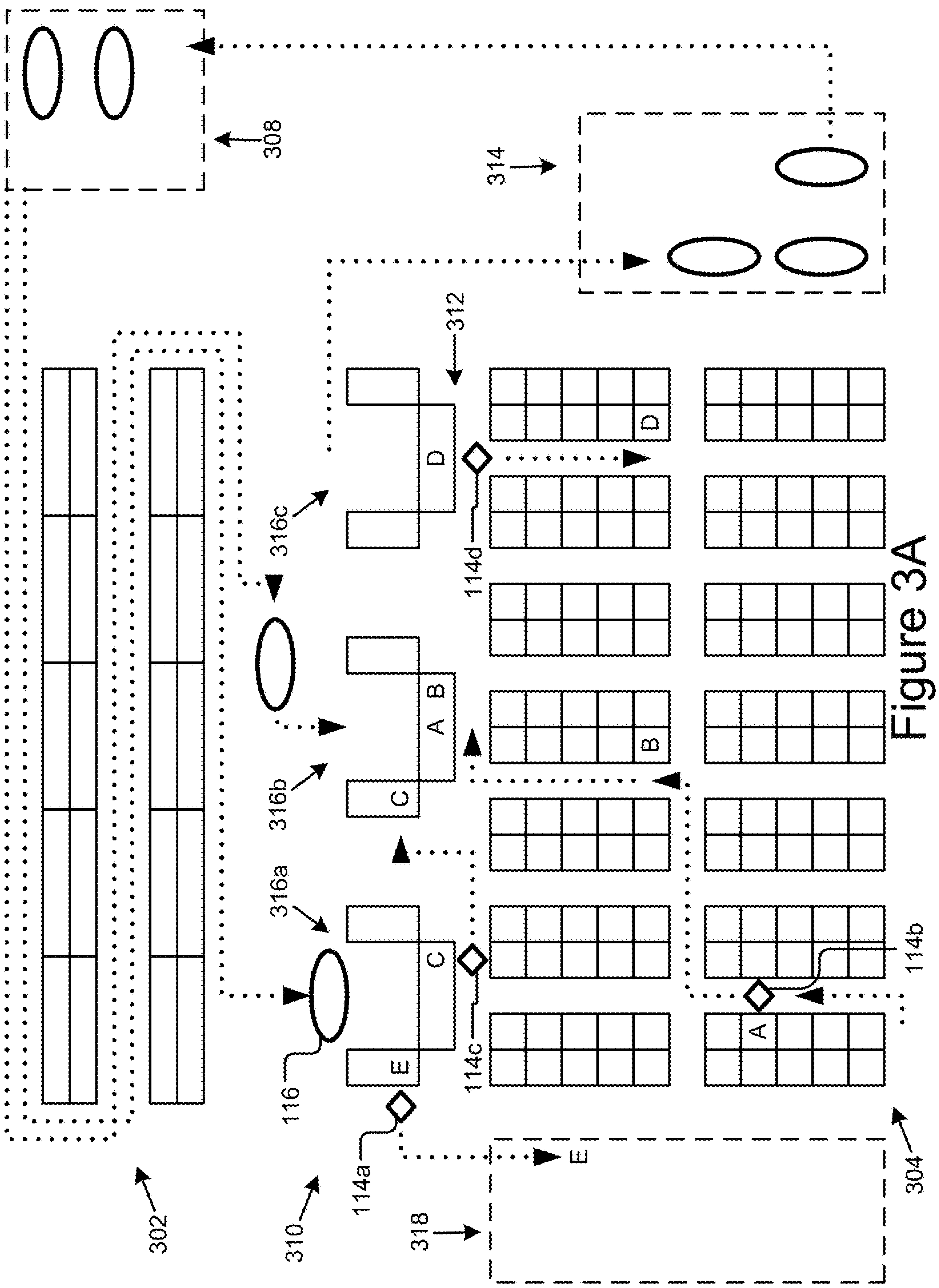

308
314
312
316c
316b
316a
114d
114c
114b
114a
116
302
310
318
304
A
B
C
D
E

Figure 3A

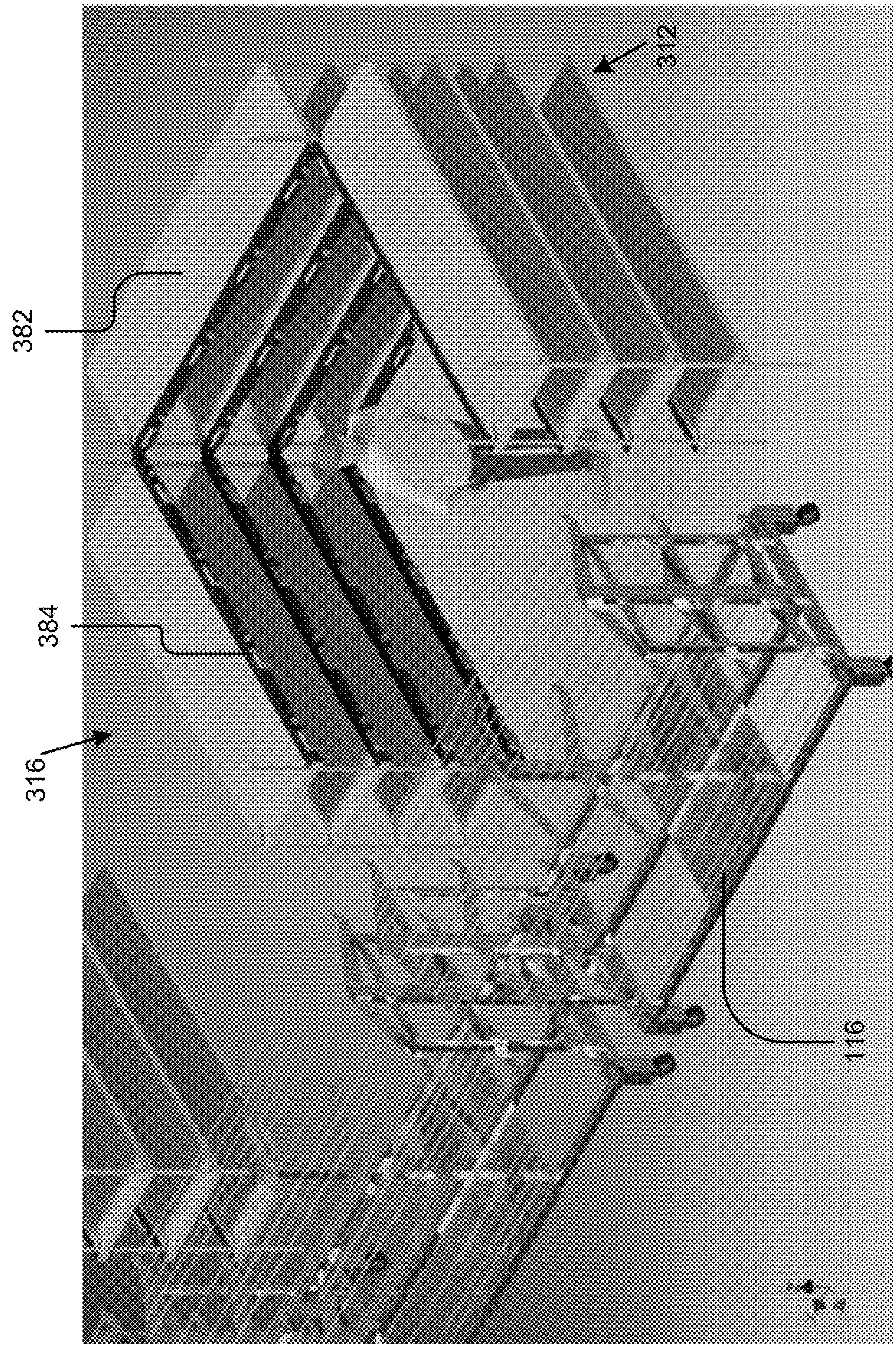


Figure 3B

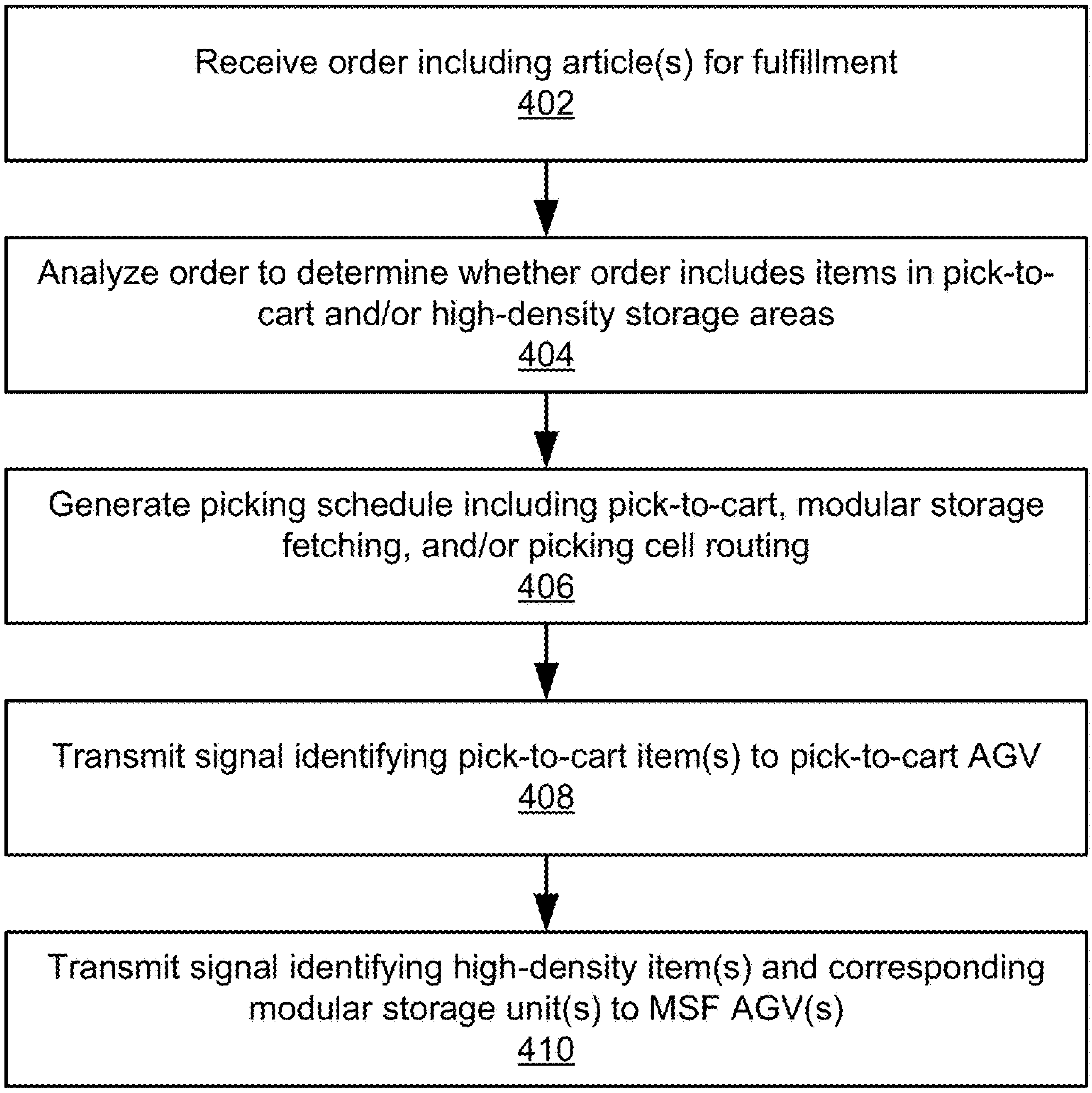

Receive order including article(s) for fulfillment
402
Analyze order to determine whether order includes items in pick-to-cart and/or high-density storage areas
404
Generate picking schedule including pick-to-cart, modular storage fetching, and/or picking cell routing
406
Transmit signal identifying pick-to-cart item(s) to pick-to-cart AGV
408
Transmit signal identifying high-density item(s) and corresponding modular storage unit(s) to MSF AGV(s)
410

Figure 4A

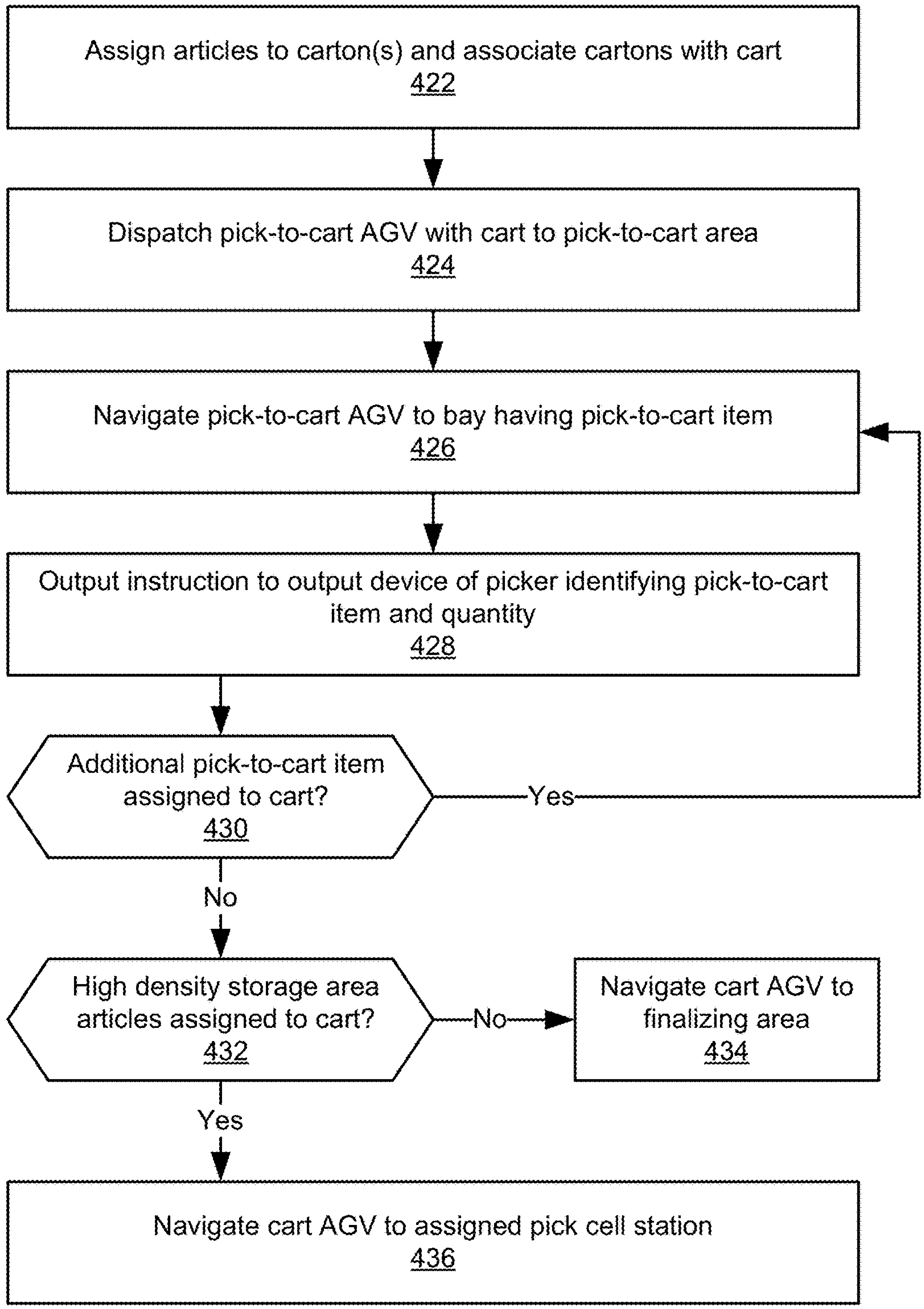

Assign articles to carton(s) and associate cartons with cart
422
Dispatch pick-to-cart AGV with cart to pick-to-cart area
424
Navigate pick-to-cart AGV to bay having pick-to-cart item
426
Output instruction to output device of picker identifying pick-to-cart item and quantity
428
Additional pick-to-cart item assigned to cart?
430
Yes
No
High density storage area articles assigned to cart?
432
No
Navigate cart AGV to finalizing area
434
Yes
Navigate cart AGV to assigned pick cell station
436

Figure 4B

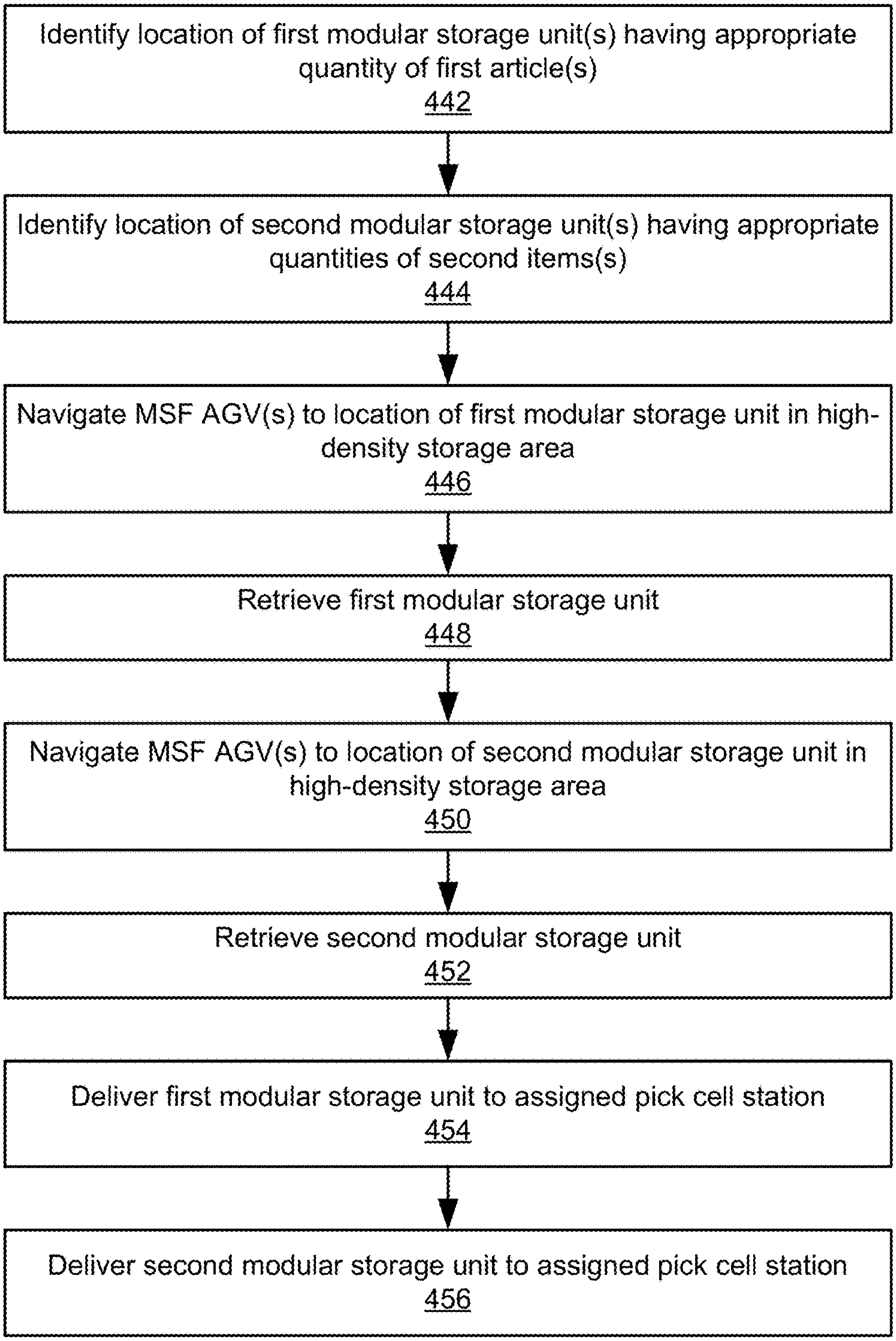

Identify location of first modular storage unit(s) having appropriate quantity of first article(s)
442
Identify location of second modular storage unit(s) having appropriate quantities of second items(s)
444
Navigate MSF AGV(s) to location of first modular storage unit in high-density storage area
446
Retrieve first modular storage unit
448
Navigate MSF AGV(s) to location of second modular storage unit in high-density storage area
450
Retrieve second modular storage unit
452
Deliver first modular storage unit to assigned pick cell station
454
Deliver second modular storage unit to assigned pick cell station
456

Figure 4C

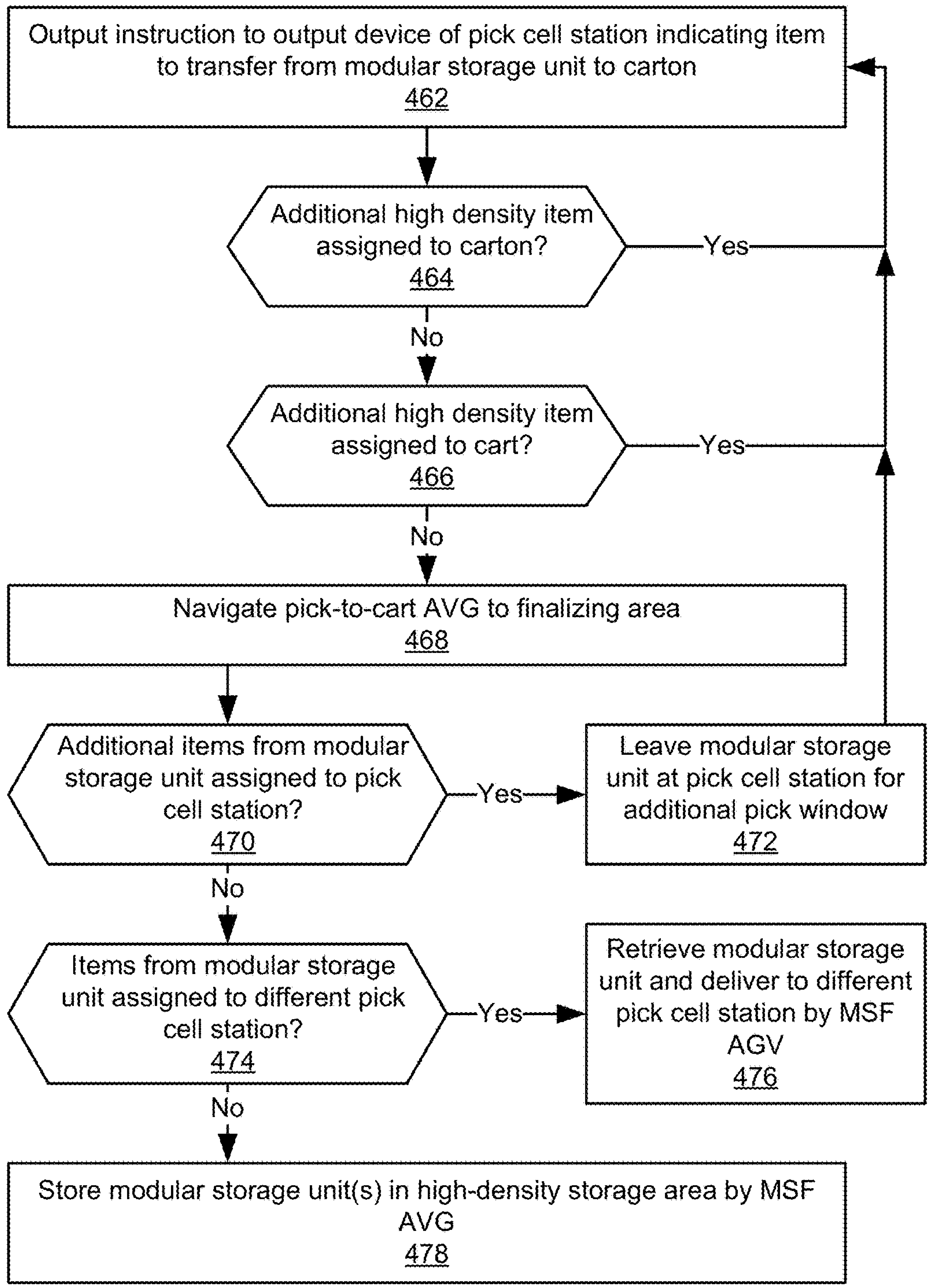

Output instruction to output device of pick cell station indicating item to transfer from modular storage unit to carton
462
Additional high density item assigned to carton?
464
Yes
No
Additional high density item assigned to cart?
466
Yes
No
Navigate pick-to-cart AVG to finalizing area
468
Additional items from modular storage unit assigned to pick cell station?
470
Yes
Leave modular storage unit at pick cell station for additional pick window
472
No
Items from modular storage unit assigned to different pick cell station?
474
Yes
Retrieve modular storage unit and deliver to different pick cell station by MSF AGV
476
No
Store modular storage unit(s) in high-density storage area by MSF AVG
478

Figure 4D

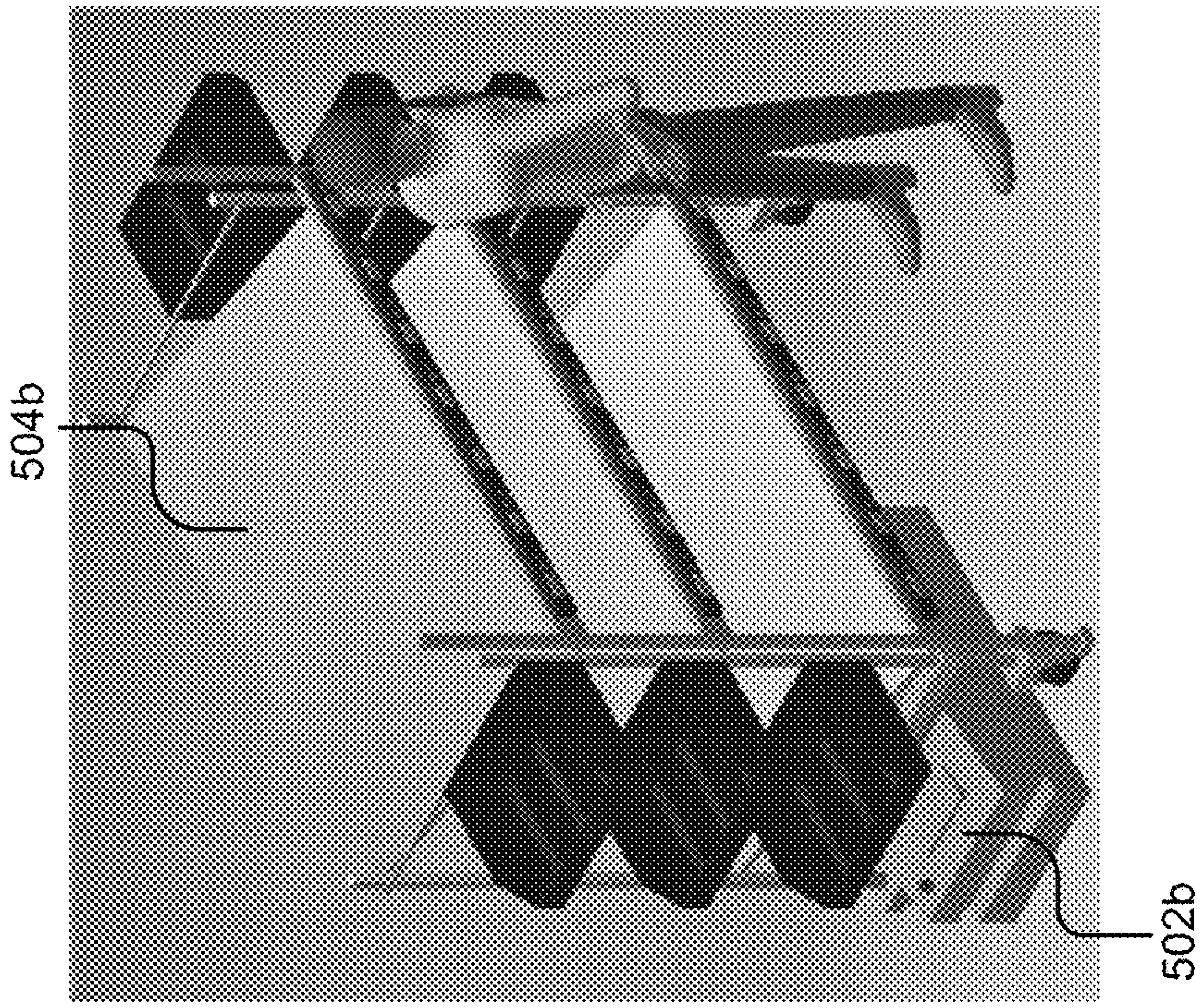


Figure 5B

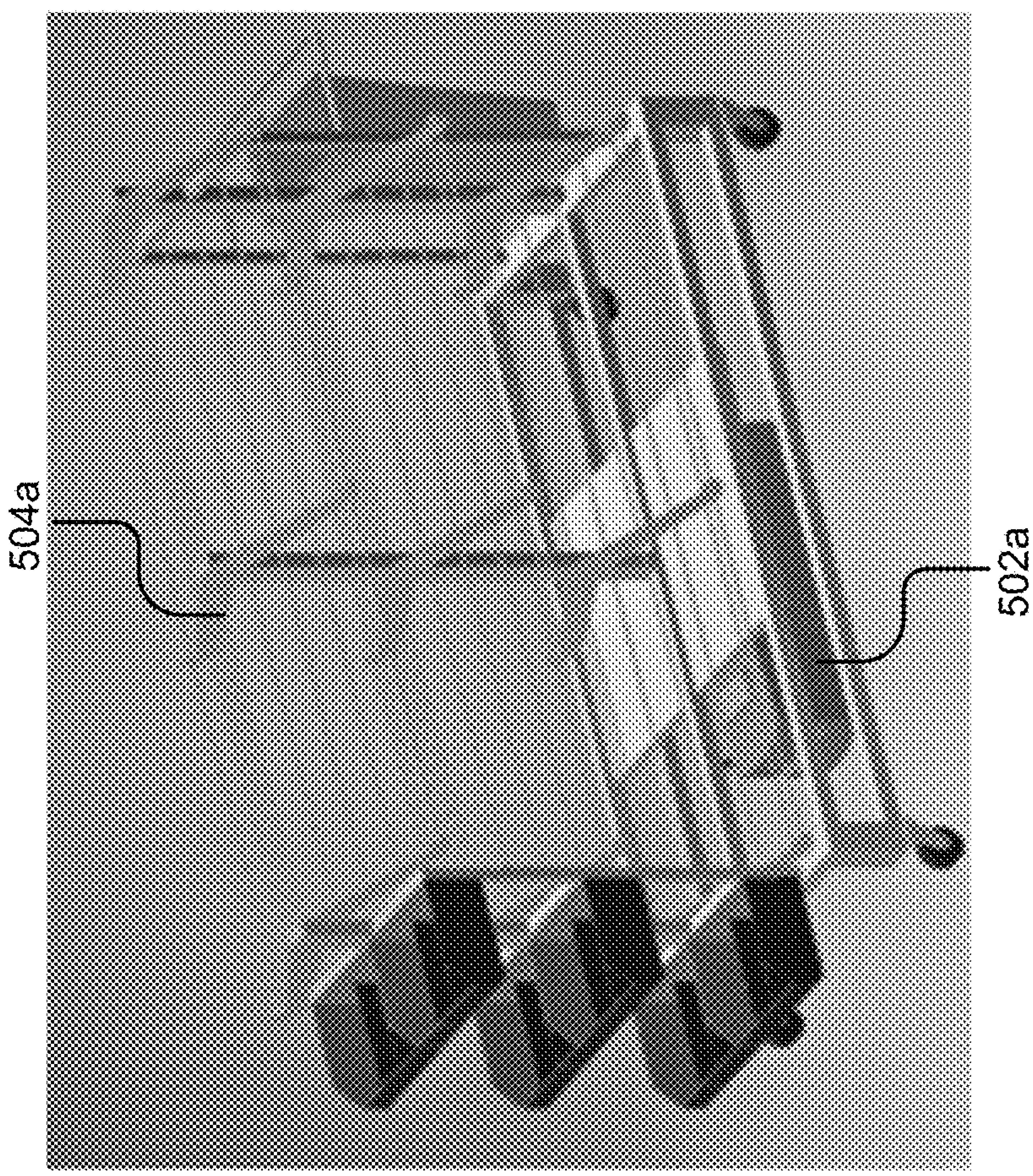


Figure 5A

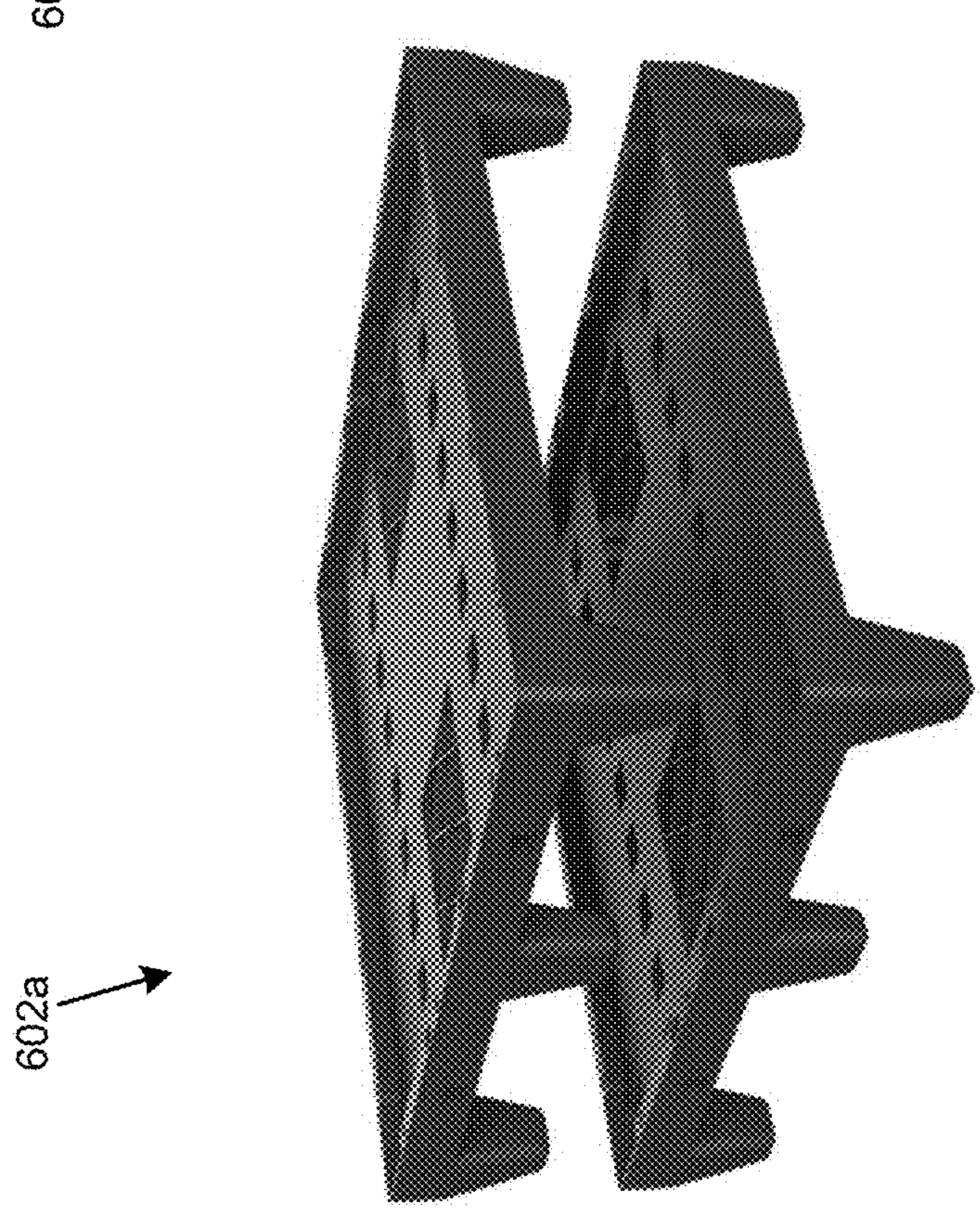


Figure 6A

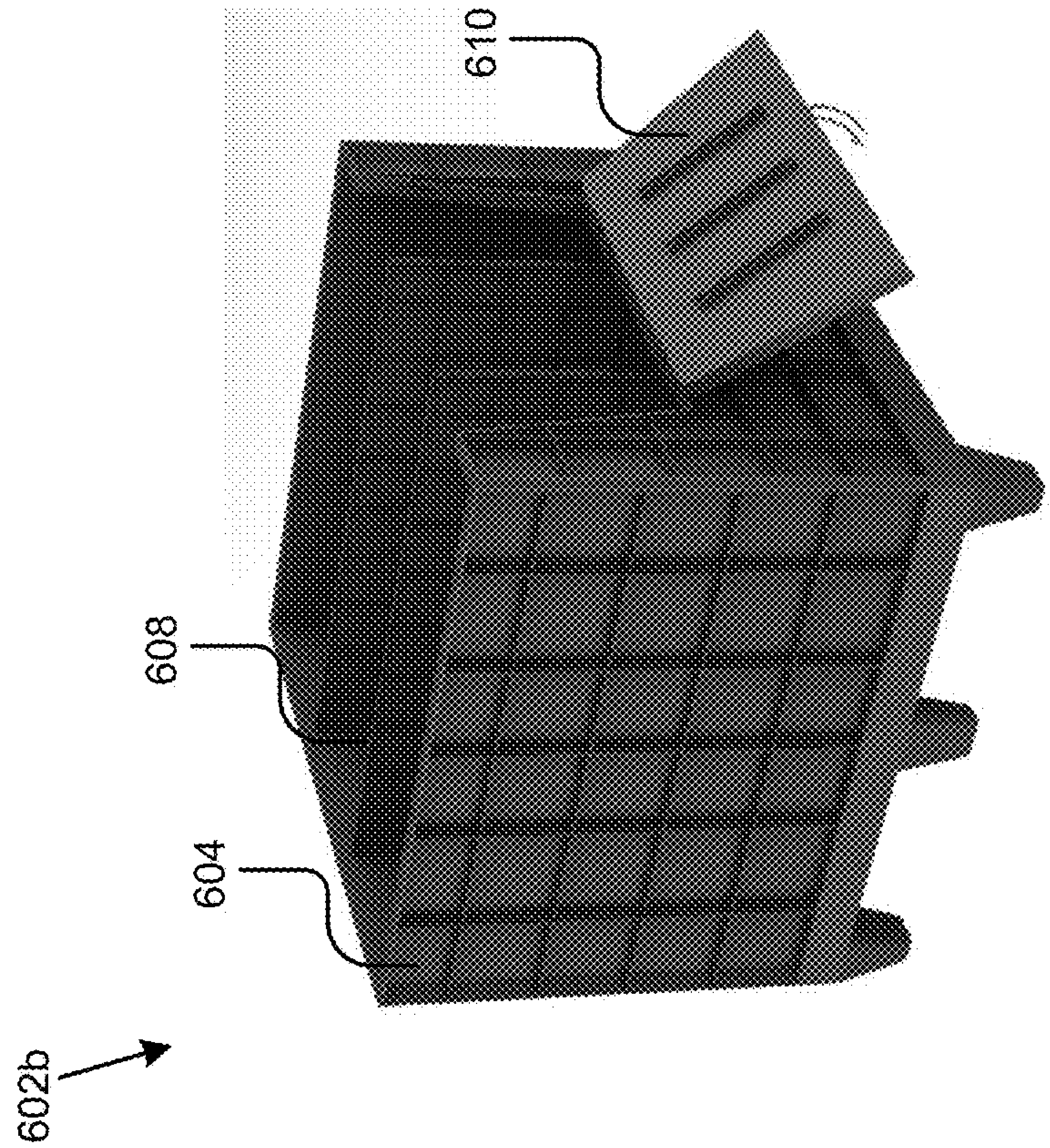


Figure 6B

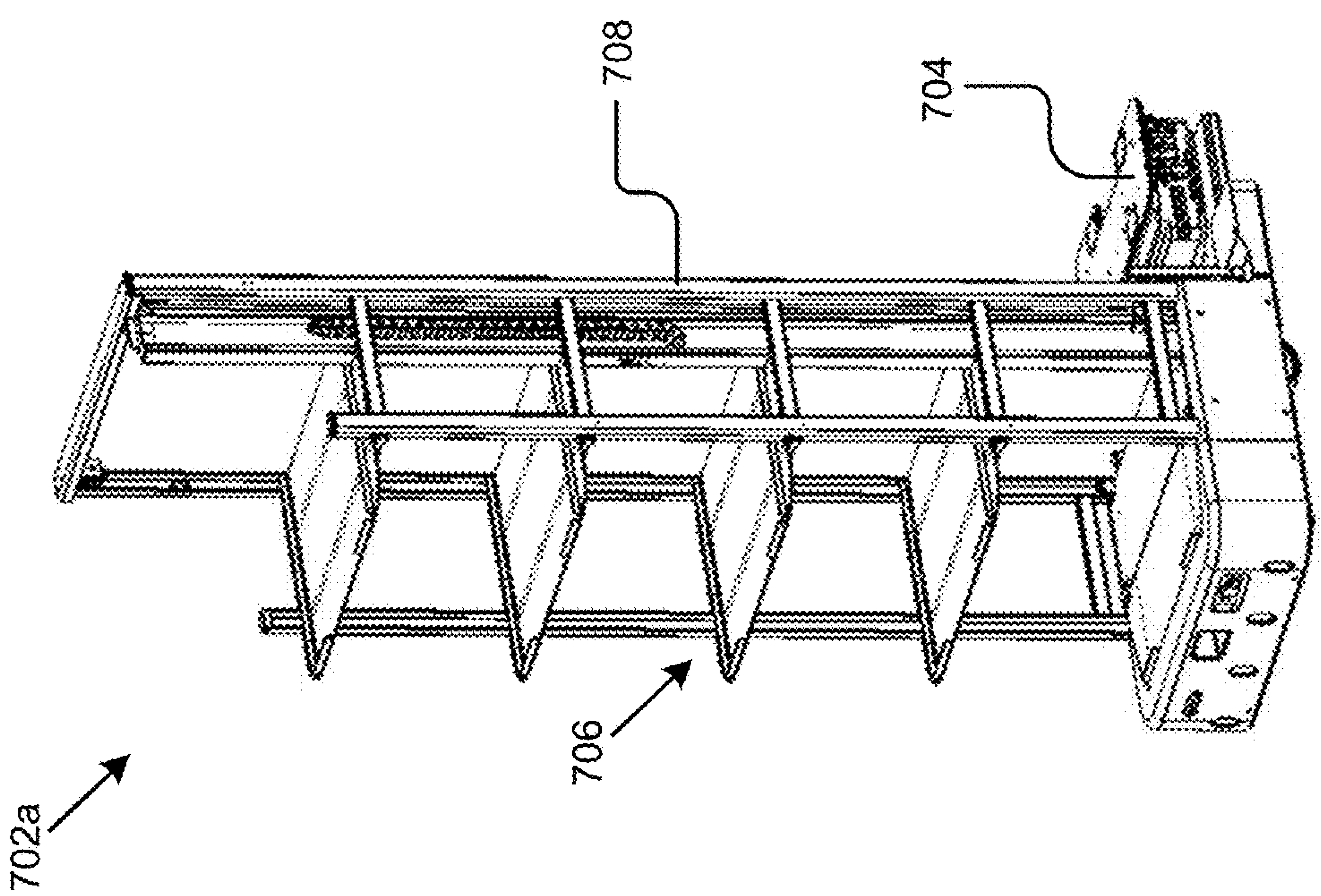


Figure 7A

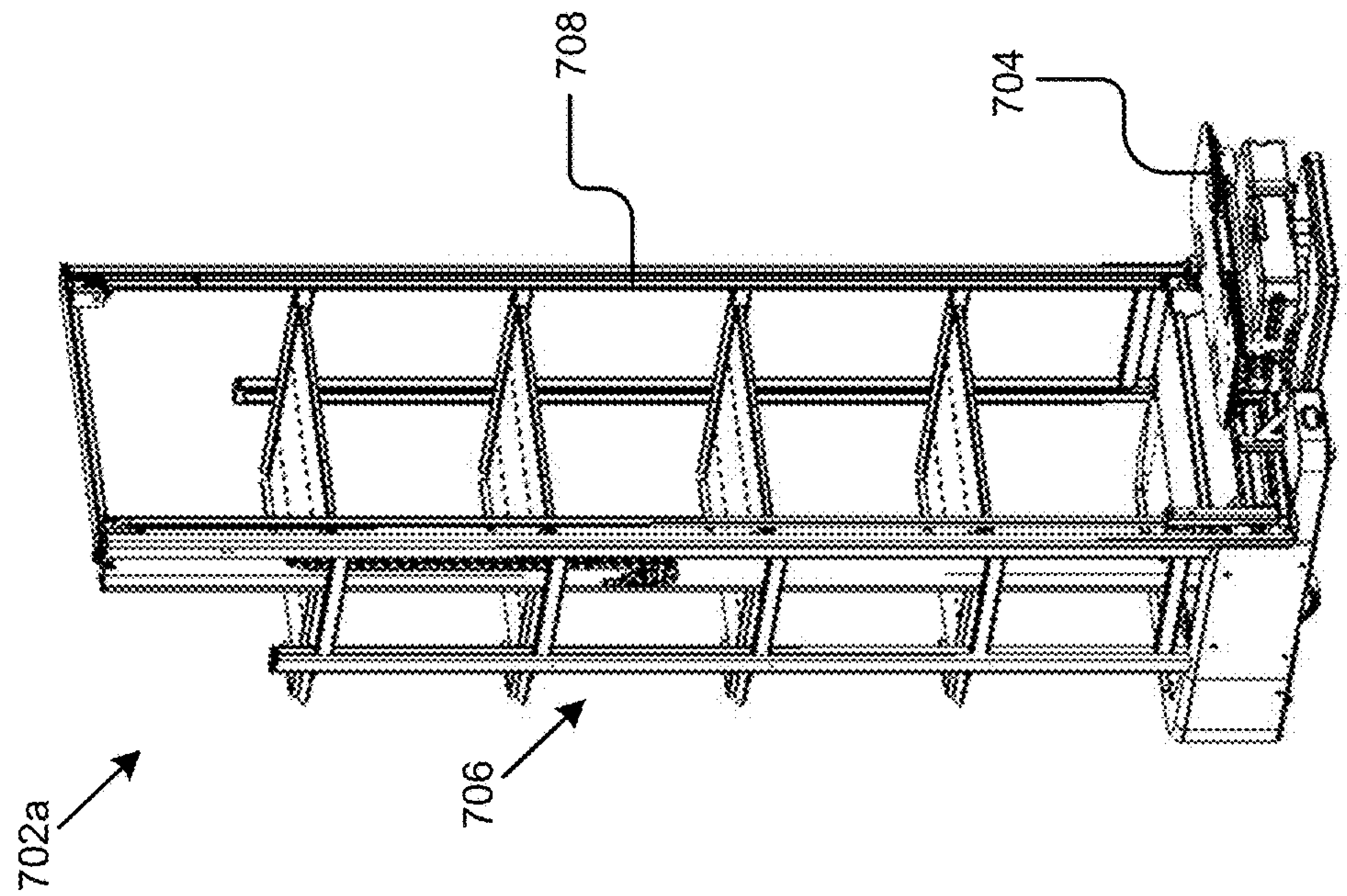


Figure 7B

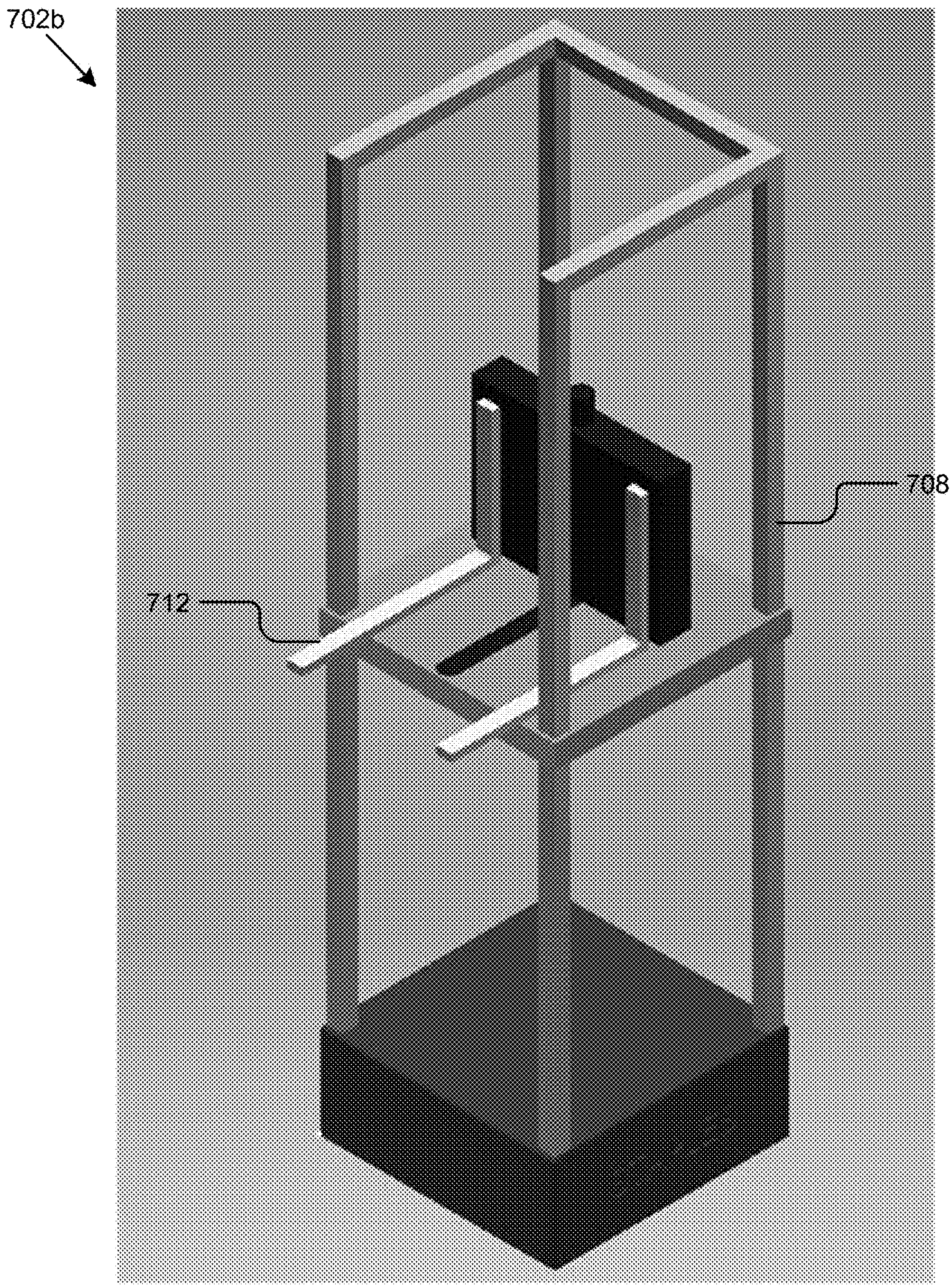


Figure 7C

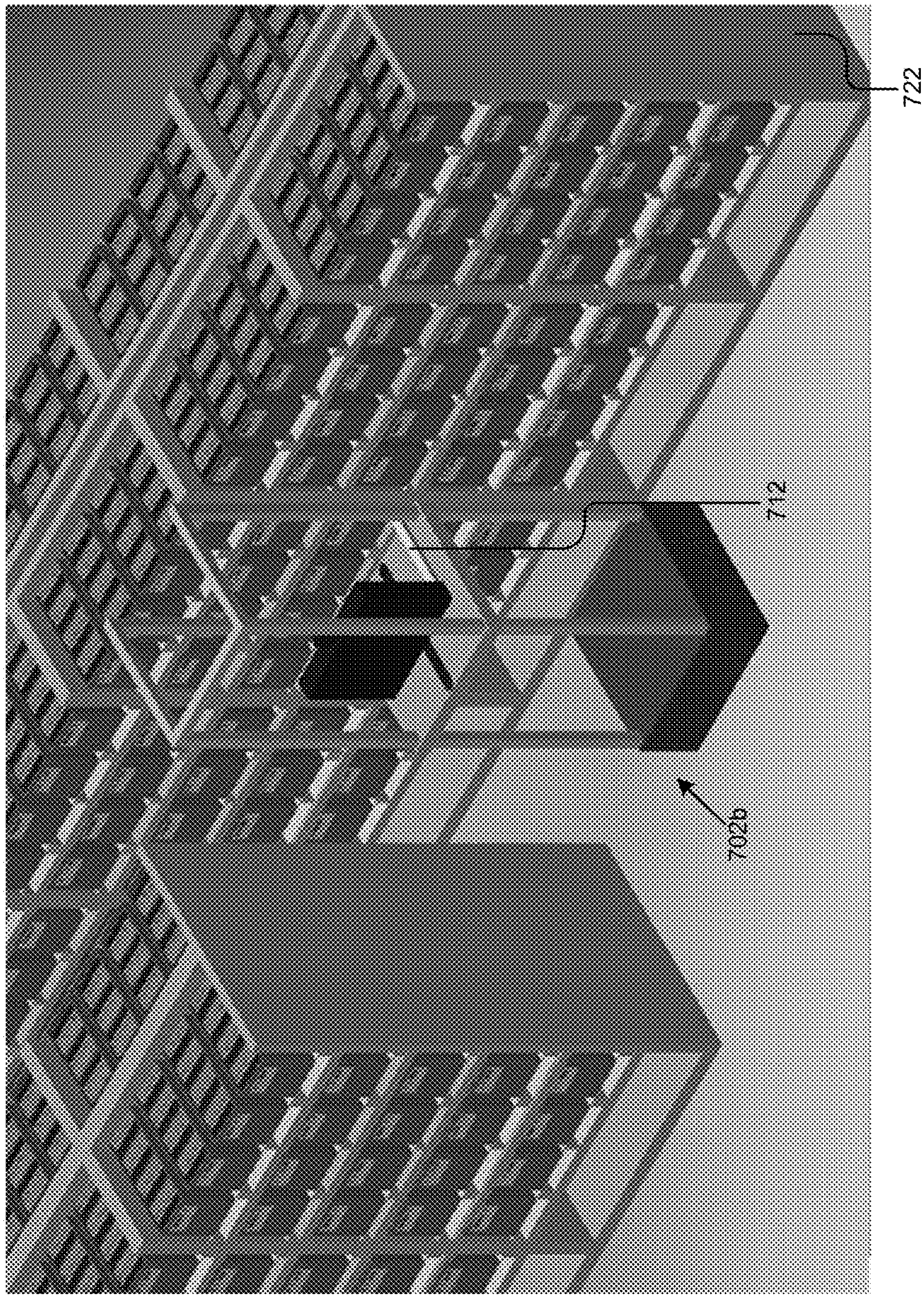


Figure 7D

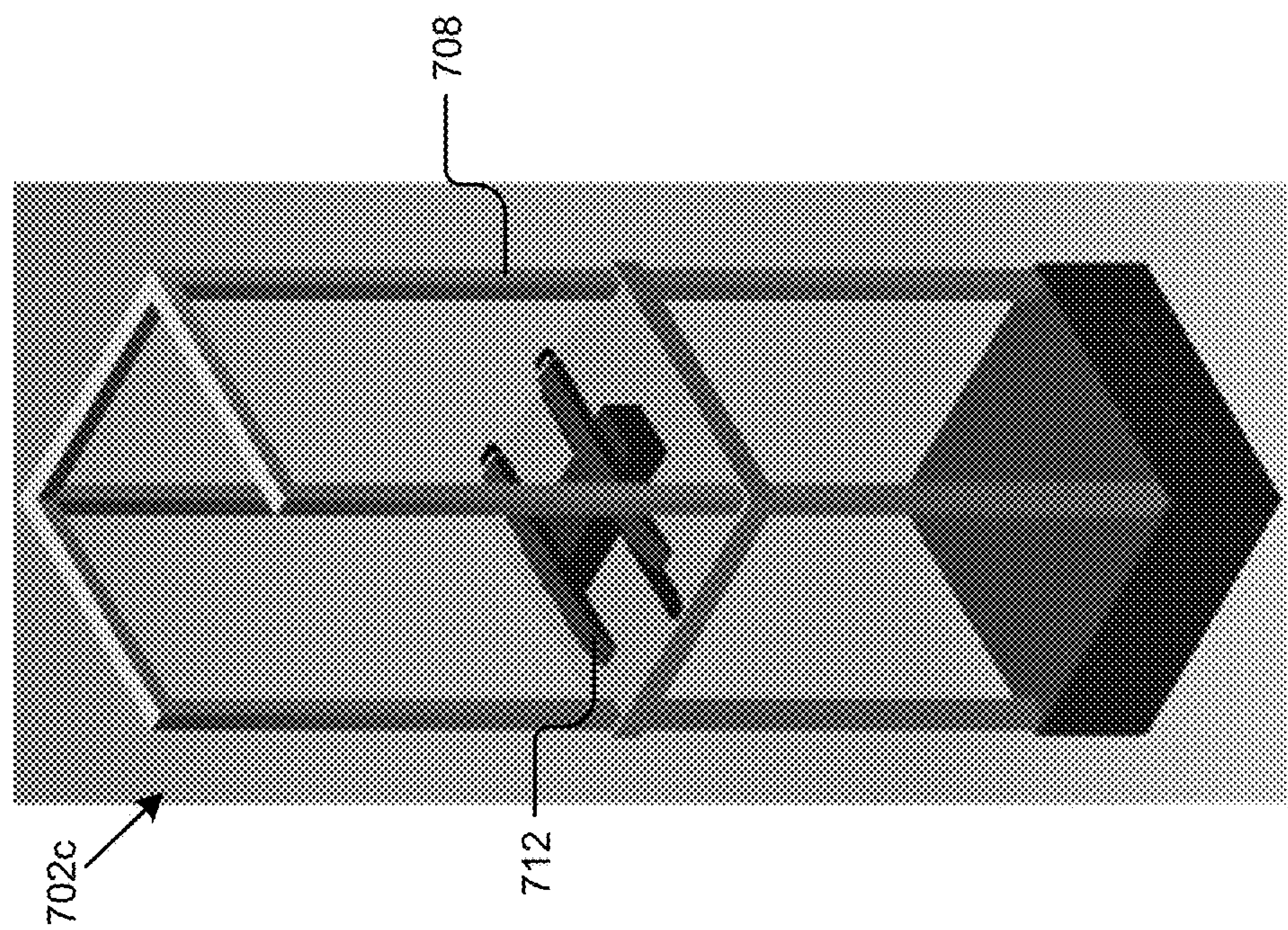


Figure 7E

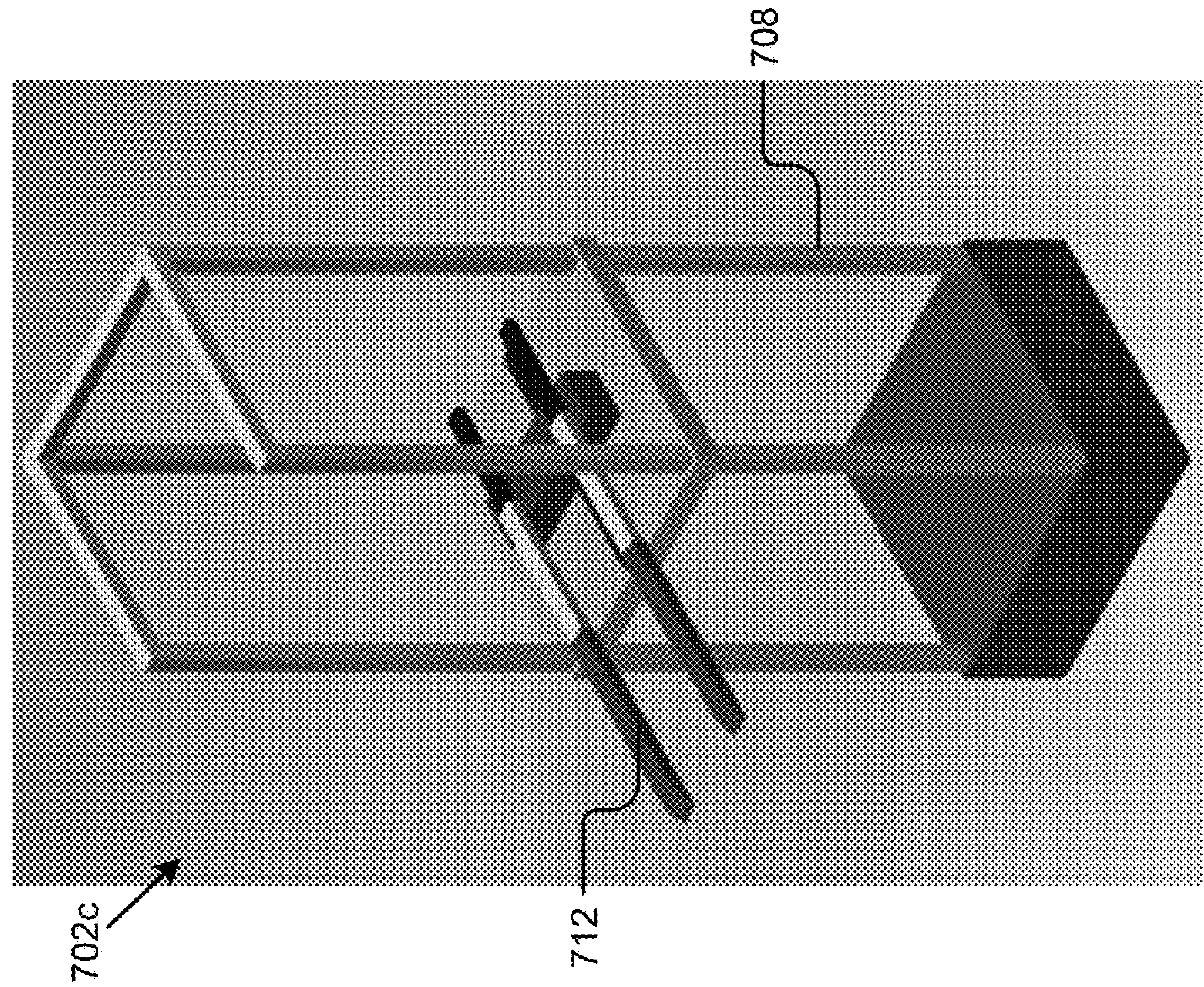


Figure 7F

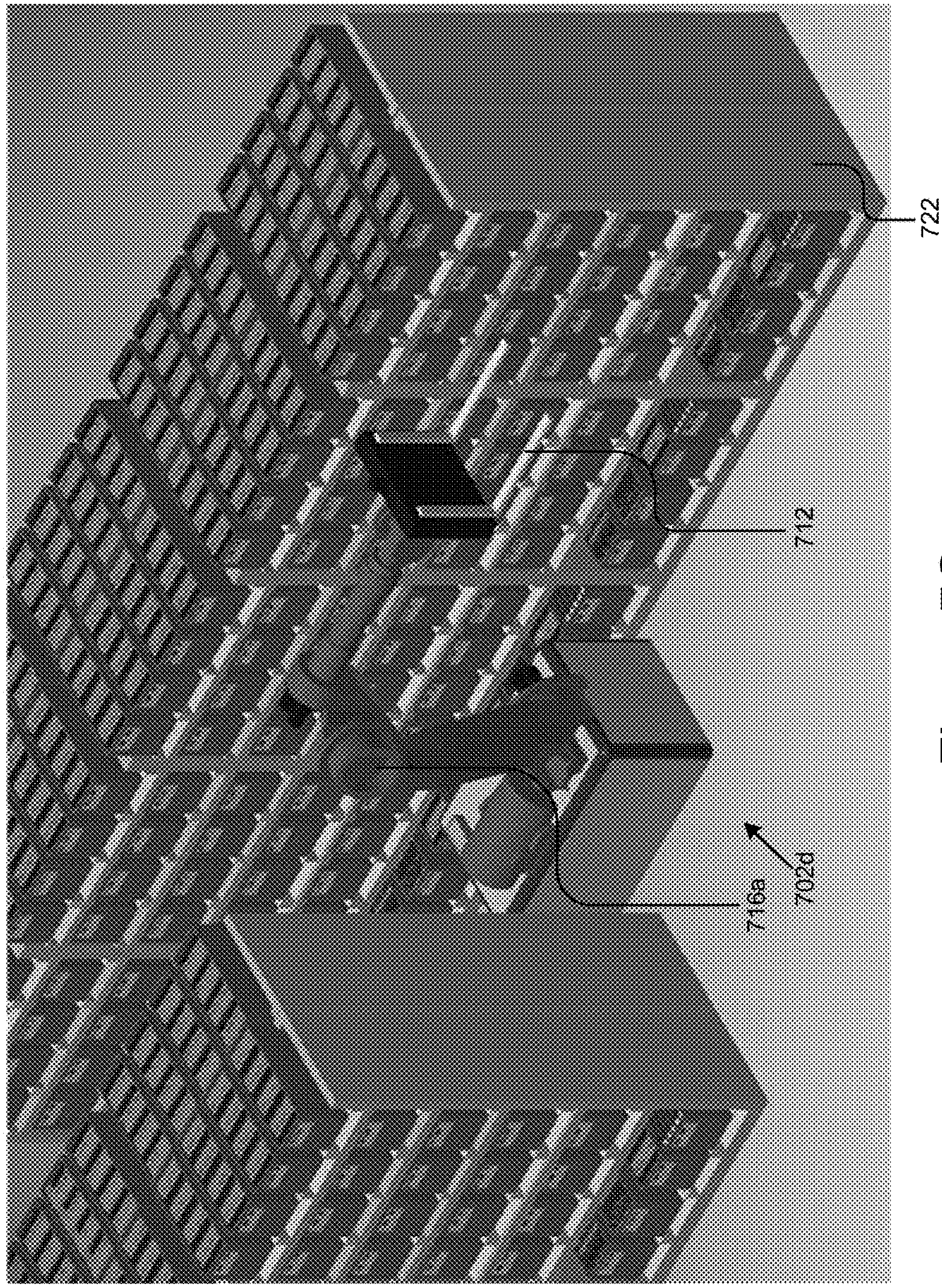


Figure 7G

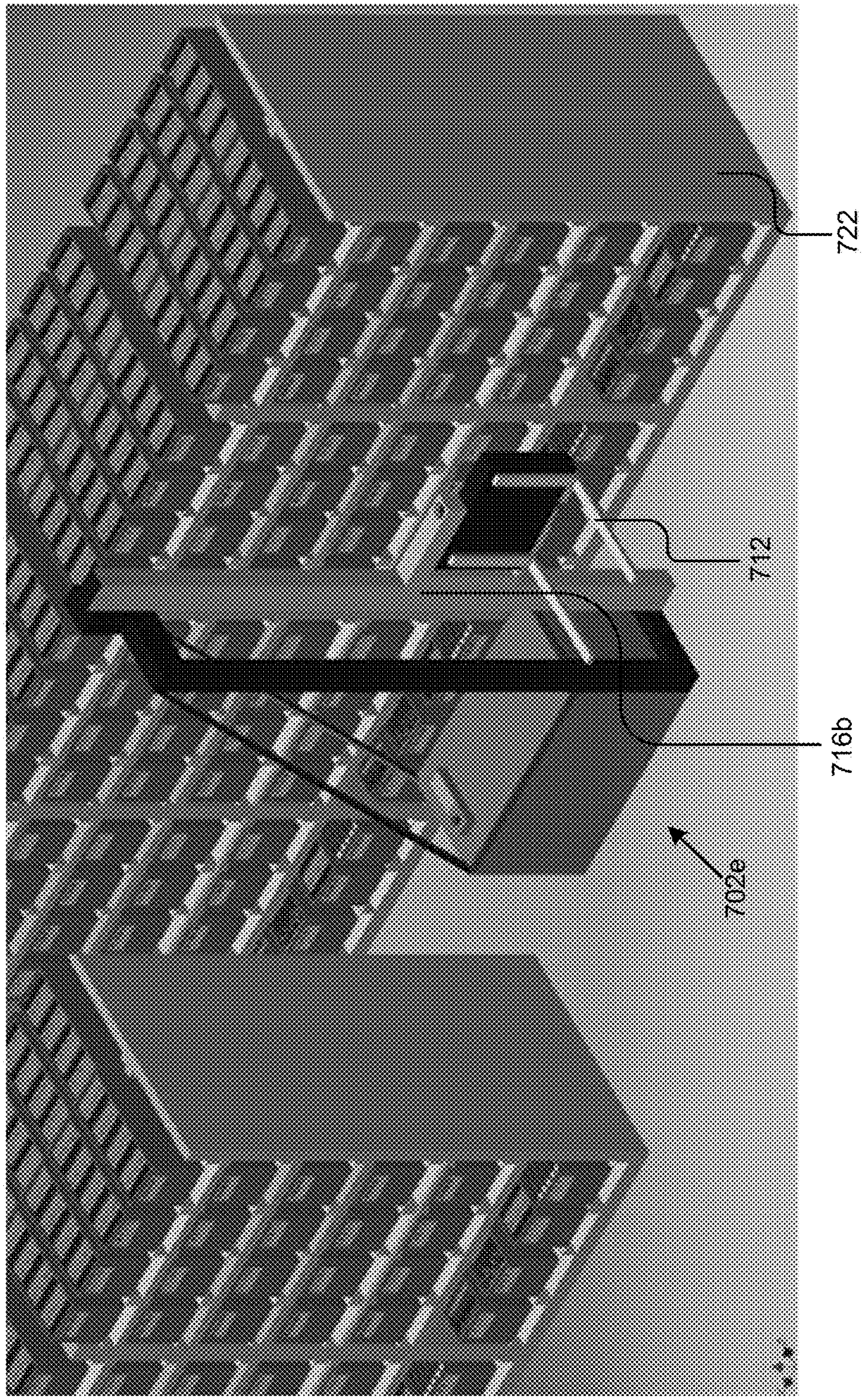


Figure 7H

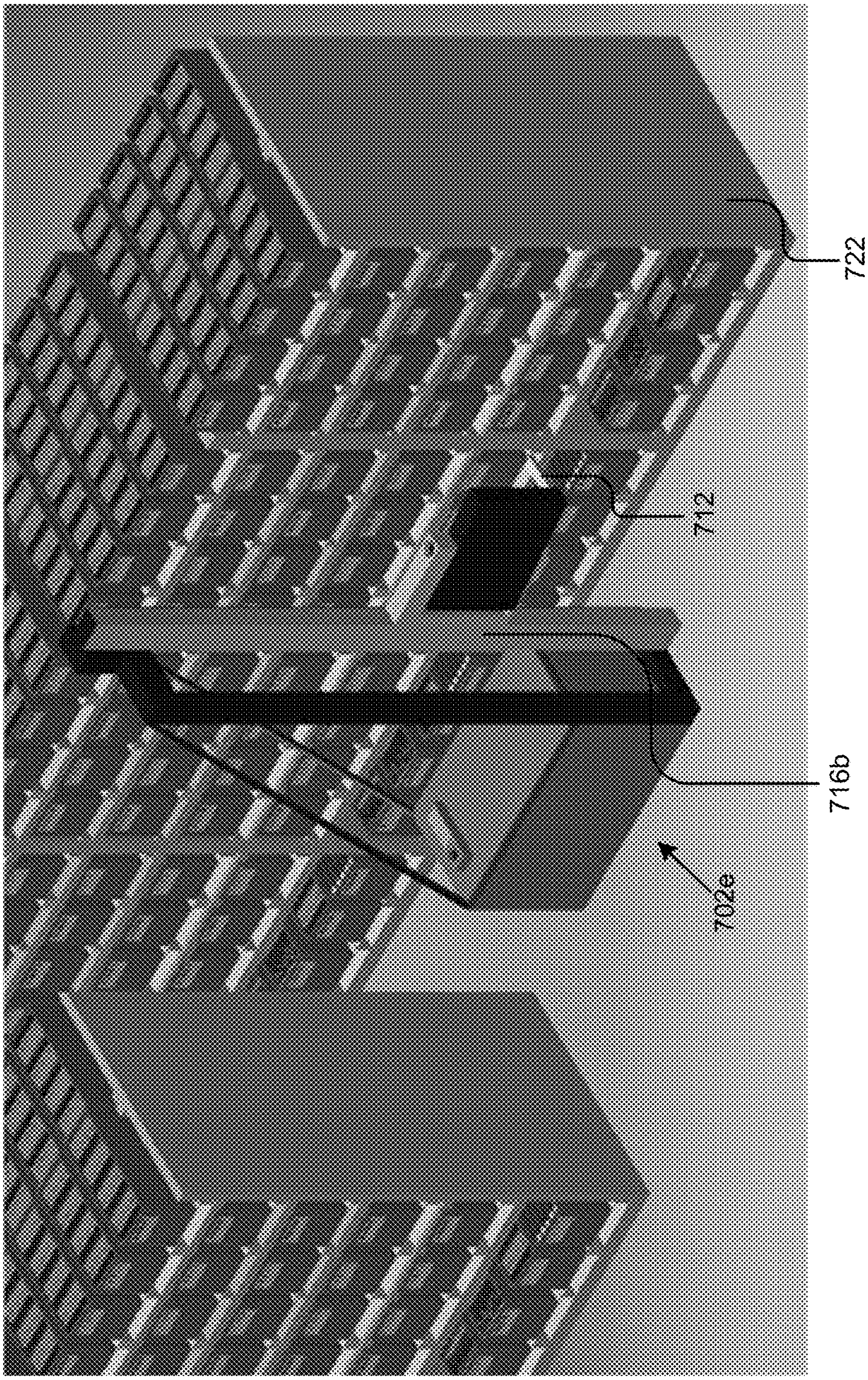


Figure 7I

HYBRID MODULAR STORAGE FETCHING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application No. 62/403,001, entitled "Modular Storage Fetching System (MSFS)," filed on Sep. 30, 2016, the entire contents of which are incorporated herein by reference.

BACKGROUND

This application relates to inventory management systems (e.g., order distribution or fulfillment systems).

Some current inventory management systems use drag-along carts on which human agents (pickers) place items they select (pick) to fulfill orders. In a zone-less pick-to-cart system an agent drags his/her cart from location to location as instructed by the computer system of the facility. The cart can accommodate multiple orders and typically is equipped with dedicated containers or cartons that are keyed to the orders being fulfilled by the agent during that cart load. In some cases, the agent wears a headset and/or is provided a terminal, such as a mobile computing device, via which the agent is provided ordered, item-by-item instructions on which items to pick. As the agent walks around the facility among the different fixed shelving units, he/she drags or pushes his/her cart manually. During a given shift, the agent may end up considerably fatigued from having to propel the cart around the warehouse.

Further, some current inventory management systems divide inventory into a series of zones and assign a human agent to a zone. The systems may use a conveyor belt to move orders across the zones as controlled by the computer system of the facility. In some cases, the agent wears a headset and/or is provided a terminal, such as a mobile computing device, via which the agent is provided ordered, item-by-item instructions on which items to pick. In some cases, pick-to-light systems use light displays to direct operators to product locations. Each product location has a numeric or alphanumeric display with a light, an acknowledgement button, and a digital readout for indicating quantity.

Further, some current inventory management or distribution systems use a "goods-to-person" approach where the items to be picked by a human agent are brought to a predetermined location to eliminate the amount of walking the human agent must do within a facility and/or expedite the picking of the items by the picker. Once picked, these items are packaged and dispatched. While these systems may, in certain use cases, adequately maneuver the items to the stations at which they are to be picked, they are less effective for high-volume and/or high-velocity goods because they have to continually return the same goods to the picking stations during the course of a day.

SUMMARY

A system can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. One general aspect includes a method including: generating, by one or more computing devices, a picking schedule including pick-to-cart routing based on order data, the order data including one or more first identification codes representing one or more first items located in a pick-to-cart area of a distribution facility; transmitting, by the one or more computing devices, a signal including the picking schedule to an automated guided vehicle (AGV) dispatching system; dispatching, by the AGV dispatching system, a cart AGV according to the picking schedule, the cart AGV including a drive unit adapted to provide motive force to the cart AGV and a guidance system adapted to locate the cart AGV in the distribution facility, the cart AGV adapted to autonomously transport cartons, the cartons adapted to hold items; autonomously navigating, by the one or more computing devices, the cart AGV through the pick-to-cart area according to the pick-to-cart routing to allow picking of the one or more first items located in the pick-to-cart area; and autonomously navigating, by the one or more computing devices, the cart AGV to a pick-cell station according to the pick-to-cart routing. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

Implementations may include one or more of the following features. The method may also include that the order data includes one or more second identification codes representing one or more second items located in a high-density storage area of the distribution facility. The method may also include that the picking schedule includes modular storage fetching (MSF) routing. The method may also include dispatching, by the AGV dispatching system, an MSF AGV according to the picking schedule, the MSF AGV including a drive unit adapted to provide motive force to the MSF AGV, a guidance system adapted to locate the MSF AGV in the distribution facility, and a modular storage unit holder adapted to hold modular storage units, the MSF AGV adapted autonomously retrieve one or more modular storage units from the high-density storage area and transport the one or more modular storage units to the pick-cell station, autonomously navigating, by the one or more computing devices, the MSF AGV to a location of the one or more modular storage units in the high-density storage area, the one or more modular storage units containing the one or more second items, and autonomously retrieving, by the MSF AGV, the one or more modular storage units from the high-density storage area. The method may further include autonomously navigating, by the one or more computing devices, the MSF AGV from the location of the one or more modular storage units in the high-density storage area to the pick-cell station according to the MSF routing. The method may also include autonomously navigating the MSF AGV to the location of the one or more modular storage units in the high-density storage area includes autonomously navigating the MSF AGV to a first location of a first modular storage unit in the high-density storage area, the first modular storage unit containing a first particular item of the one or more second items, and autonomously navigating the MSF AGV from the first location of the first modular storage unit to a second location of a second modular storage unit, the second modular storage unit containing a second particular item of the one or more second items. The method may also include autonomously retrieving, by the MSF AGV, the one or more modular storage units, autonomously retrieving, by the MSF AGV, the first modular storage unit from the first location of the first modular storage unit in the high-density storage area, and autonomously retrieving, by the MSF AGV, the second modular storage unit from the second location of the second modular storage unit. The method where the second location of the second modular storage unit is a second pick-cell station. The method where the second location of the second modular storage unit is a different location of the high-density storage area than the first location of the first modular storage unit. The method may also include autonomously navigating the MSF AGV from the location of the one or more modular storage units in the high-density storage area to the pick-cell station. The method may also include autonomously delivering, by the MSF AGV, the first modular storage unit to the pick-cell station. The method where the MSF AGV is further adapted to stage the one or more modular storage units at a staging area of the pick-cell station. The method where the MSF AGV is adapted to retrieve multiple sizes of modular storage units. The method may also include that the one or more modular storage include and a holding structure adapted to hold items, the holding structure adapted to interface with a retrieval mechanism of the MSF AGV. The method may also include that the MSF AGV includes the retrieval mechanism adapted to interface with the holding structure to retrieve a given modular storage unit from a modular storage unit support structure and place the given modular storage unit in the modular storage unit holder. The method may also include that the retrieval mechanism of the MSF AGV includes a fork coupled with the MSF AGV and is configured to lift the given modular storage unit and remove the given modular storage unit from the modular storage unit support structure. The method may also include that the modular storage unit support structure includes a shelf. The method may also include that the modular storage unit holder of the MSF AGV is adapted to hold a plurality of modular storage units. The method may also include that the modular storage unit holder of the MSF AGV includes a plurality of bays, each bay adapted to hold a modular storage unit. The method may also include that the retrieval mechanism is adapted to place the given modular storage unit in any of the plurality of bays. The method where the pick-cell station includes an output device configured to provide picking instructions to a picker, the picking instructions indicating to the picker which of the one or more second items from the one or more modular storage units to place in a given carton held on the cart AGV. The system further including an MSF AGV including a drive unit adapted to provide motive force to the MSF AGV, a guidance system adapted to locate the MSF AGV in the distribution facility, and a modular storage unit holder adapted to hold modular storage units, the MSF AGV adapted autonomously retrieve one or more modular storage units from the high-density storage area and transport the one or more modular storage units to the pick-cell station. The system where the MSF AGV is further configured to autonomously navigate to a location of the one or more modular storage units in the high-density storage area, the one or more modular storage units containing a second item, and autonomously retrieve the one or more modular storage units from the high-density storage area. The system where the MSF AGV is further configured to autonomously navigate from the location of the one or more modular storage units in the high-density storage area to the pick-cell station, and autonomously deliver the one or more modular storage units to the pick-cell station. The system where the AGV dispatching system is further configured to dispatch a MSF AGV according to the picking schedule. Implementations of the described techniques may include hardware, a method or process, or computer software on a computer-accessible medium.

Another general aspect includes a method including: dispatching, by an AGV dispatching system, a cart AGV according to a picking schedule, the cart AGV including a drive unit adapted to provide motive force to the cart AGV and a guidance system adapted to locate the cart AGV in a distribution facility, the cart AGV adapted to autonomously transport cartons, the cartons adapted to hold items; dispatching, by the AGV dispatching system, a MSF AGV according to the picking schedule, the MSF AGV including a drive unit adapted to provide motive force to the MSF AGV and a guidance system adapted to locate the MSF AGV in the distribution facility, the MSF AGV adapted to hold a plurality of modular storage units and retrieve the plurality of modular storage units from a high-density storage area and transport the plurality of modular storage units to a pick-cell station; autonomously navigating, by the one or more computing devices, the cart AGV through a pick-to-cart area according to the picking schedule to retrieve a first item located in the pick-to-cart area; autonomously navigating, by the one or more computing devices, the cart AGV to the pick-cell station according to the picking schedule; autonomously navigating the MSF AGV to a first location of a first modular storage unit in the high-density storage area, the first modular storage unit containing a second item; autonomously retrieving, by the MSF AGV, the first modular storage unit from the first location; autonomously navigating the MSF AGV from the first location to a second location of a second modular storage unit, the second modular storage unit containing a third item; autonomously retrieving, by the MSF AGV, the second modular storage unit from the second location; and autonomously delivering, by the MSF AGV, the first modular storage unit and the second modular storage unit to the pick-cell station. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

Another general aspect includes a system including: a warehouse execution system adapted to generate a picking schedule including pick-to-cart routing based on order data, the order data including one or more first identification codes representing one or more first items located in a pick-to-cart area of a distribution facility, and transmit a signal including the picking schedule to an AGV dispatching system; an AGV dispatching system adapted to dispatch a cart AGV according to the picking schedule, the cart AGV including a drive unit adapted to provide motive force to the cart AGV and a guidance system adapted to locate the cart AGV in the distribution facility, the cart AGV adapted to autonomously transport cartons, the cartons adapted to hold items; and the cart AGV adapted to autonomously navigate through the pick-to-cart area according to the pick-to-cart routing to retrieve the one or more first items located in the pick-to-cart area, autonomously navigate to a pick-cell station according to the pick-to-cart routing. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

Other embodiments of one or more of these aspects include corresponding systems, apparatus, and computer programs, configured to perform the actions of the methods, encoded on computer storage devices.

It should be understood that the language used in the present disclosure has been principally selected for readability and instructional purposes, and not to limit the scope of the subject matter disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure is illustrated by way of example, and not by way of limitation in the figures of the accompanying drawings in which like reference numerals are used to refer to similar elements.

FIG. **1** is a block diagram of an example system and data communication flow for a hybrid modular storage fetching system.

FIG. **2** is a flowchart of an example method for picking an order in a hybrid modular storage fetching system.

FIG. **3**A is a schematic of an example configuration of a distribution facility layout in a hybrid modular storage fetching system.

FIG. **3**B is an illustration of an example pick-cell station.

FIG. **4**A is a flowchart of an example method for receiving and routing order data.

FIG. **4**B is a flowchart of an example method for picking pick-to-cart items using a cart automated guided vehicle.

FIG. **4**C is a flowchart of an example method for retrieving items in modular storage units from a high-density storage area using a modular storage fetching automated guided vehicle.

FIG. **4**D is a flowchart of an example method for combining items from different zones of the distribution facility at a pick-cell station.

FIGS. **5**A and **5**B are illustrations of an example cart automated guided vehicles.

FIGS. **6**A-**6**B are illustrations of example modular storage units.

FIGS. **7**A-**7**I are illustrations of example modular storage fetching automated guided vehicles.

DESCRIPTION

Among other benefits, the technology described herein improves upon that described in the Background Section. For instance, the technology provides robotic devices, systems, methods, and other aspects that can more efficiently process goods (e.g., items or items in a distribution facility) based on demand. Further, the technology can reduce the amount of irrelevant items carried simultaneously with relevant items by providing automated guided vehicle(s) (AGV(s)) that are configured to efficiently carry items.

With reference to the figures, reference numbers may be used to refer to components found in any of the figures, regardless whether those reference numbers are shown in the figure being described. Further, where a reference number includes a letter referring to one of multiple similar components (e.g., component **000***a*, **000***b*, and **000***n*), the reference number may be used without the letter to refer to one or all of the similar components.

The technology described herein can be integrated into any logistics system, dispatch system **106**, warehouse execution system **102**, warehouse management system **104**, etc., to coordinate the provision of to-be-picked items in a hybrid modular storage fetching system. This technology beneficially improves productivity and throughput, increases asset utilization, and lowers cycle time and labor costs. These benefits, in turn, lead to shorter delivery times and result in significant savings and business value.

FIG. **1** depicts an example system **100** and data communication flow for implementing a hybrid modular storage fetching system. The system **100** includes a warehouse execution system (WES) **102**. The WES **102** is coupled to equipment **110** (e.g., conveyor controls, conveyor scanners, conveyors, automated induction equipment, other warehouse equipment, etc.), a warehouse management system (WMS) **104**, a data store **120** storing warehouse management, execution, dispatch, picking, carton, order, item, AGV, map, and/or other data, a picking system **108** (e.g., pick-to-voice, pick-to-light, etc.), and a dispatch system **106**.

The WES **102** may, in some embodiments, include one or more hardware and/or virtual servers programmed to perform the operations, acts, and/or functionality described herein. For instance, the WES **102** may include an AGV management engine and a SKU routing engine. These components may comprise software routines storable in one or more non-transitory memory devices and executable by one or more computer processors of the WES **102** to carry out the operations, acts, and/or functionality described herein. In further embodiments, these routines, or a portion thereof, may be embodied in electrical hardware that is operable to carry out the operations, acts, and/or functionality described herein.

The AGV management engine is executable to generate a schedule that defines the route for an AGV during a picking session, as described herein. For a given cart AGV **116***a* . . . **116***n*, depending on the items (e.g., identified by stock keeping units or SKUS) to be placed in the cartons of that cart, the AGV management engine generates a schedule and transmits it to the dispatch system **106**, which in turn deploys a cart AGV **116** according to the schedule, for instance. In some implementations, the dispatch system **106** instructs the AGV to proceed through one or more of the picking zones of the distribution facility according to the schedule. The schedule of each of the AGVs may be coordinated such that an optimal flow can be achieved, as discussed elsewhere herein.

The SKU (e.g., a stock keeping unit or unique identifier identifying an item) routing engine is executable to route items into different storage zones depending based on picking profiles of the items, which may be stored and maintained as item data **130**. The SKU routing engine dynamically monitors the picking activity in the distribution facility, tracks which items have the highest volume or velocity for a given timeframe, stores the tracking data in the data store **120**, and can instruct the AGV management engine to have items relocated by AGVs to different storage locations in the distribution facility based on the tracked picking activity.

A picking profile of a given item can change over time as demand for the item changes. The demand for a given item may be random or predicable (e.g., seasonal), and may change based on time of day, week, month, year, etc. The item routing engine may maintain the picking profile in the database as item data **130**, and utilize that data to determine in which zone of the distribution facility to store the item.

Advantageously, based on the picking profiles (e.g., velocity and volume), the SKU routing engine may provide a distinct automated application for picking. In some implementations, the SKU routing engine may continually algorithmically evaluate the picking profile of each SKU and instruct the WES **102** and dispatch system **106** to transfer/relocate items to another storage location and/or picking area, swap item locations, etc., when necessary to maintain the most expedient flow in the facility. This advantageously reduces capital associated with fully automated high velocity items and reduces replenishment complexity.

The WES **102** may store productivity information for points in the distribution facility in a database (e.g., a non-transitory data store **120**). The productivity information may reflect mechanical capacity of that given point of the AGV system. In some cases, the mechanical capacity may be dynamic based on current conditions (e.g., system health, staffing levels (e.g., number of associates working in zone), stock levels, operational state, etc.).

In some embodiments, the WMS **104** and/or WES **102** may algorithmically analyze the configuration of a cart AGV **116** depending on items that are set for distribution/fulfillment in the next picking time window. The WMS **104** and/or WES **102** may generate a stocking list for the cart based on hub, priority, pick density, pick zone demand, and item-to-item affinity, etc. The AGV management engine may use the stocking list when generating the schedule for the cart AGV **116**.

The dispatch system **106** may be electronically communicatively coupled to a plurality of AGVs. The dispatch system **106** includes hardware and software configured to dispatch the AGVs, and is coupled for communication with the WES **102** and WMS **104** to receive instructions and provide data. The dispatch system **106** calculates a route to execute the task considering traffic and resources. In some cases it adjusts the route or the task in order to keep the route optimum.

The AGVs are robotic vehicles including drive units providing motive force for moving the AGVs (and, in some instances, carts, modular storage units **602**, etc.), guidance systems for determining position of the AGVs within the distribution facility, and equipment for carrying items. The equipment for carrying items may include carton holders or modular storage unit holders (e.g., carts, shelves, etc.), for example, as described in further detail in reference to FIGS. **5**A-**7**I. FIGS. **5**A-**7**I depict types of AGVs, such as modular storage fetching (MSF) AGVs **114** and cart AGVs **116**.

A cart AGV **116** is an automated guided vehicle or robot configured to autonomously transport pick-to-cart items from a pick-to-cart area **302** of the distribution facility to a pick-cell station **316** and/or finalizing area **314** (e.g., as described in reference to FIG. **3**A). The cart AGV **116** may include a drive unit adapted to provide motive force to the cart AGV **116** and a guidance system adapted to locate the cart AGV **116** in the distribution facility. In some implementations, the cart AGV **116** is adapted to autonomously transport a carton holder (e.g., a cart or shelves) that is, in turn, adapted to hold cartons. Cartons may include, for instance, a box (e.g., a shipping box) adapted to hold items. For example, a cart AGV **116** may push/pull a cart (e.g., a carton holder) holding cartons around a pick-to-cart area **302** and may automatically stop at storage bays of the pick-to-cart area **302** where items to be picked are stored, so that a picker in the pick-to-cart area **302** can easily place items into one or more of the cartons. In some instances, the cart AGV **116** may transport the cart to a pick-cell station **316** to receive additional items into the cartons from high-density storage (e.g., from modular storage units **602** in high-density storage, as described below). In some instances, the cart AGV **116** may move at walking speed next to, behind, or in front of a picker walking through the pick-to-cart area **302** of the distribution facility. Additional details of example cart AGVs **116** are shown in reference to FIGS. **5**A and **5**B.

An MSF AGV **114***a* . . . **114***n* is an automated guided vehicle or robot configured to autonomously transport items from a high-density storage area **304** of the distribution facility to a pick-cell station **316**, replenishment area **318**, and/or finalizing area **314**. The MSF AGV **114** may include a drive unit adapted to provide motive force to the MSF AGV **114**, a guidance system adapted to locate the MSF AGV **114** in the distribution facility, and a modular storage unit holder adapted to hold modular storage units **602**. In some implementations, an MSF AGV **114** may autonomously retrieve modular storage unit(s) **602** containing items to be picked in an order. For instance, the MSF AGV **114** may transport the modular storage unit(s) **602** to a pick-cell station **316**, so that a picker at the pick-cell station **316** can pick items from the modular storage unit(s) **602** and place them into cartons in a cart. For example, a cart AGV **116** may transport a carton to a bay in the pick-to-cart area **302** having a first item in an order, then to a pick-cell station **316** where a separate MSF AGV **114** has delivered or will deliver a second item (e.g., in a modular storage unit **602**) in the order, so that a picker can place the second item into the carton with the first item. The system may coordinate the timing, placement, and movement of the cartons, modular storage units **602**, pick-cell station **316** workload, and AGVs to bring cartons and modular storage units **602** having items corresponding to an order to the same pick-cell station **316** during the same time window, as described in further detail herein. Additional details of example MSF AGVs **114** are described in reference to FIGS. **7**A-**7**I.

The WMS **104** may, in some embodiments, include one or more hardware and/or virtual servers or software routines storable in one or more non-transitory memory devices and executable by one or more processors to perform the operations, acts, and/or functionality described herein. The WMS **104** may be configured to store and maintain carton data **124** in the data store **120**. The carton data **124** includes information about cartons in the system, such as a unique identifier for each carton, a carton type, the zones the carton will visit, the number of pick lines the carton proceed through, and the priority for the carton. Some cartons may have a higher priority relative to other cartons and the system may expedite handling of those cartons with higher priority relative to other cartons in the system. The carton data **124** may include a picklist defining the items the carton will contain. The WMS **104** may store data mapping items to the different pick zones (e.g., the pick-to-cart area **302**, the high-density storage area **304**, a particular modular storage unit **602**, a particular location at a particular pick-cell station **316**, etc.). In some implementations, the WMS **104** may be configured to communicate the carton data **124** with the WES **102**, the picking system **108**, and/or dispatch system **106** in real time, in batches, as requested by these components, etc.

The picking system **108** may, in some embodiments, include one or more hardware and/or virtual servers or software routines storable in one or more non-transitory memory devices and executable by one or more processors to perform the operations, acts, and/or functionality described herein. The picking system **108** may receive pick confirmations, for example, from pickers or operators (e.g., using barcode scanners, NFC, RFID chips, or other sensors or input methods) working within a pick zone (e.g., a pick-to-cart area **302**, pick-cell station **316**, etc.) confirming that picks for a given carton have been performed, as described in further detail below. An example picking system **108** may include an available pick-to-voice or a pick-to-light system. The picking system **108** may be configured to communicate the pick confirmation data with the WES **102**, WMS **104**, or other components of the system in real time, in batches, as requested by the components of the system, etc.

The picking system **108** may receive confirmatory input (e.g., pick confirmations) from pickers working within a pick zone. The confirmatory input confirms that all picks for a given carton have been completed. The picking system **108** transmits the confirmatory input to the WES **102**. The confirmatory input may include the time stamp reflecting completion of the picks in the zone, a unique identifier identifying the picker (operator), a unique identifier identifying the pick zone, a unique identifier identifying the AGV, and/or a unique identifier identifying the carton (e.g. a carton number).

The data store **120** is an information source for storing and providing access to data. The data stored by the data store **120** may be organized and queried using various criteria including any type of data stored by it. The data store **120** may include data tables, databases, or other organized collections of data. An example of the types of data stored by the data store **120** may include, but is not limited to map data **122**, AGV data **128**, carton data **124**, order data **126**, modular storage unit data, etc. In some instances, the data store **120** may also include, conveying system attributes, picking data, picker attributes, sensor data, etc.

The data store **120** may be included in the WES **102**, WMS **104**, or in another computing system and/or storage system distinct from but coupled to or accessible by the WES **102**, WMS **104**, or other components of the system **100**. The WES **102**, picking system **108**, and/or dispatch system **106**, for example, may store and maintain map data **122**, order data **126**, carton data **124**, and AGV data **128**. The data store **120** can include one or more non-transitory computer-readable mediums for storing the data. In some implementations, the data store **120** may store data associated with a database management system (DBMS) operable on a computing system. For example, the DBMS could include a structured query language (SQL) DBMS, a NoSQL DMBS, various combinations thereof, etc. In some instances, the DBMS may store data in multi-dimensional tables comprised of rows and columns, and manipulate, e.g., insert, query, update and/or delete, rows of data using programmatic operations.

The map data **122** may include data reflecting the 2 or 3 dimensional layout of the facility including the location of modular storage units **602**, picking areas, lanes, equipment **110**, etc. Map data **122** may indicate the attributes of the distribution facility, including attributes of zones (e.g., one or more pick-to-cart areas **302**, high-density storage areas **304**, induction zones **308**, finalizing areas **314**, pick-cell stations **316**, replenish stations, etc.). For example, attributes of zones may include the number, quantity, and location of shelving units or bays, modular storage units **602**, items, guidance system locators, etc. In some implementations, the map data **122** may include the location of guidance system locators.

The order data **126** includes data about picking including orders, items picked, items to be picked, picking performance, picker identities, pick confirmations, locations items are picked from, etc. Order data **126** may indicate the quantity and identity of items in orders, shipping addresses, order priority, progress of order fulfillment, number of cartons in an order, etc.

Item data **130** may describe items available for picking in a distribution facility. The item data **130** may include unique identifiers for these items, the item volume (e.g., the total amount picked in given window (e.g., in an hour, day, etc.)), the item velocity (e.g., number of different times item picked in given window (e.g., per hour, day etc.), the unique location of the items within the distribution facility (isle, shelf, shelf position, etc.), other attributes of the item (e.g., size, description, weight, quantity of items in a package, color, etc.), item inventory, mapping of items of modular storage units **602**, etc. In some implementations, the item data **130** may include the quantity of particular items a modular storage unit **602** contains, the current location of a modular storage unit **602**, a preferred storage location of items and/or modular storage units **602**, a threshold inventory level of items to be satisfied before autonomously transporting the modular storage unit **602** to a replenishment area **318** by an MSF AGV **114** (e.g., to restock the items in the modular storage unit **602**).

The AGV data **128** may describe the state of an AGV (operational state, health, location, battery life, storage capacity, items being carried, cartons, etc.), whether picker assigned to it, etc.

The components of the system may be coupled to exchange data via wireless and/or wired data connections. The connections may be made via direct data connections and/or a computer network. The computer network may comprise any number of networks and/or types of networks, such as wide area networks, local area networks, virtual private networks, cellular networks, close or micro proximity networks (e.g., Bluetooth, NFC, etc.), etc. In some embodiments, one or more of these components may be coupled via a data communications bus.

FIG. **2** is a flowchart of an example method for picking an order in a hybrid modular storage fetching system. At **202**, the WES **102** may generate a picking schedule including pick-to-cart routing, modular storage fetching (MSF) routing, and/or pick-cell routing based on order data **126**. The order data **126** may include one or more first unique identification codes representing one or more first items located in a pick-to-cart area **302** of a distribution facility. In some instances, the order data **126** may also include one or more second unique identification codes representing one or more second items located in a high-density storage area **304** of the fulfilment facility.

The pick-to-cart routing describes routing of a particular cart AGV **116***a* . . . **116***n* through a pick-to-cart area **302**. For example, the pick-to-cart routing may include a picking list of pick-to-cart items to be picked to the cartons transported by the cart AGV **116**. The pick-to-cart routing may indicate the location of the storage units, shelves, or bays in which an item in the picking list is located. In some implementations, the pick-to-cart routing may also include a defined route of a cart AGV **116** through these locations and an indication of locations at which to stop the cart AGV **116**, so that a picker can pick items from adjacent storage units, shelves, or bays into the cartons transported by the cart AGV **116**. The pick-to-cart routing may also include a schedule indicating when to pick items and when to deliver cartons to a particular pick-cell station **316**.

The MSF routing describes routing of a particular MSF AGV **114** through a high-density storage area **304**. For example, the MSF routing may include a picking list of items stored in modular storage units **602**, unique identification codes of the modular storage units **602**, and the current locations of the modular storage units **602**. In some instances, the current location of the modular storage units **602** may be in the high-density storage area **304**, in a replenishment area **318**, or at a pick-cell station **316**. The MSF routing may also include a defined route of an MSF AGV **114** through the distribution facility to retrieve one or more modular storage units **602** including items from one or more orders and deliver those modular storage units **602** to assigned pick-cell stations **316**. The defined route may be calculated to most efficiently retrieve one or a series of modular storage units **602**, maximize a quantity of modular storage units **602** for the MSF AGV **114** to retrieve in a single trip, to avoid traffic of other AGVs, and/or to cause the modular storage unit(s) **602** to arrive at a pick-cell station **316** at a minimized time difference from a carton (e.g., transported by a separate cart AGV **116**) arriving at the same pick-cell station **316** to which the item in the modular storage unit **602** is to be placed, for example. The MSF routing may also include a schedule indicating when to retrieve modular storage units **602** and when to deliver the modular storage units **602** to a particular pick-cell station **316**.

Pick-cell routing may describe routing of AGVs among pick-cell stations **316**. For instance, a modular storage unit **602** may be transferred by an MSF AGV **114** from one pick-cell station **316** to another pick-cell station **316**, as described elsewhere herein.

In some implementations, the WES **102** may determine, based on load information in one or more of the pick zones, that a particular zone, picker, path, pick-cell station **316**, etc., has a high traffic load. In response to such a determination, the WES **102** may dynamically adjust the routing schedule, for example, dictating which cart AGVs **114** or MSF AGVs **116** are sent into different zones of the distribution facility. For example, the WES **102** may determine that there is a threshold level of traffic (e.g., by cart AGVs **114**) in the pick-to-cart area **302**, in response to which determination, the WES **102** may induct AGVs (e.g., cart AGVs **114** with particular orders to be filled) into the hybrid modular storage fetching system that bypass the pick-to-cart area **302** and proceed directly to pick-cell stations **316** to receive items from modular storage units **602**. In another example implementation, the WES **102** may determine, for instance, that there is a threshold level of traffic in a staging area **312** or that no MSF AGVs **116** are available to retrieve items from high-density storage **304** and may, in response, induct cart AGVs into the system that do not stop at a pick-cell station **316** or that require fewer modular storage units **602** to be retrieved from high-density storage. Accordingly, in some implementations, the WES my dynamically balance the load of various zones, AGVs, pick-cell stations, etc., in the system by adapting the composition (e.g., items from pick-to-cart versus from high-density storage) of orders/cartons on a particular AGV (e.g., a cart AGV), for example.

At **204**, the WES **102** or picking system **108** may transmit a signal including the picking schedule (or components thereof) to the dispatching system **106**.

At **206**, the dispatching system **106** may dispatch a cart AGV **116** according to the picking schedule. In some implementations, dispatching a cart AGV **116** may include creating cartons, assigning the cartons to a cart to be transported by a cart AGV **116**, placing the cartons on the cart, and, in some instances, coupling the cart AGV **116** with the cart. For instance, the WES **102** may assign orders (or items thereof) to cartons. Labels with unique identification codes identifying the cartons may be printed, placed on cartons, and the cartons may be placed on the cart at an induction area **308**. The unique identification codes of the cartons may match, in the data store **120**, the carton (and therefor the cart/cart AGV **116**) with items to be picked.

At **208**, the dispatching system **106** may dispatch an MSF AGV **114** according to the MSF routing.

At **210**, the cart AGV **116** may autonomously navigate along a path through the pick-to-cart area **302** according to the pick-to-cart routing to retrieve one or more items located in the pick-to-cart area **302**. As described elsewhere herein, the cart AGV **116** may follow the guidance system through the pick-to-cart area **302** and stop at designated areas for items stored in those areas to be picked to the designated cartons. In some implementations, the cart, carton, cart AGV **116**, storage area, or separate computing device (e.g., a mobile device of a picker) may include an output device provide output indicating items to be picked at a particular location and, in some implementations, the output device may also include an input to receive pick confirmations. Once the pick confirmation has been received, the cart AGV **116** may autonomously move to the next area to pick a subsequent item assigned to a carton on the cart.

Once items in the pick-to-cart storage area have been picked to the cart AGV **116**, the cart AGV **116** may autonomously navigate to an assigned pick-cell station **316** or to a finalizing area **314** according to the pick-to-cart routing. In some implementations, the cart AGV **116** may decouple from the cart and leave the cart at the pick-cell station **316** (or at a finalizing area **314**) so that the cart AGV **116** may transport another cart while the first cart is being filled with items from modular storage units **602**, for example.

At **212**, the MSF AGV **114** may autonomously navigate to a location of the one or more modular storage units **602** in the high-density storage area **304** (or a replenishment area **318**, pick-cell station **316**, etc.), the one or more modular storage units **602** containing one or more items in an order, for example, an order with a carton transported by a cart AGV **116**, as described above. The MSF AGV **114** may autonomously retrieve the one or more modular storage units **602** from the high-density storage area **304**, for example. The MSF AGV **114** may then autonomously navigate from the location of the modular storage unit(s) **602** to the pick-cell station **316** according to the MSF routing to transport the modular storage unit(s) **602** to the pick-cell station **316**. In some implementations, the MSF AGV **114** may hold a plurality of modular storage units **602** and may deliver each of the modular storage units **602** to the same pick-cell station **316** or to separate pick-cell stations **316**. In some implementations, the MSF AGV **114** may also retrieve modular storage units **602** that are no longer needed at a particular pick-cell station either separately or while delivering new modular storage units **602** to the pick-cell station.

At **214**, the picking system **108** outputs instructions to an output device (e.g., on the cart, pick-cell station, modular storage unit **602**, or separate computing device, etc.), the instructions directing a picker at a pick-cell station to transfer items from modular storage unit(s) **602** at the pick-cell station to carton(s) on the cart.

FIG. **3**A depicts a schematic of an example configuration of a distribution facility. It should be understood that various distribution facilities may include different picking zones having different stocking infrastructure and picking configurations. For instance, high-volume and/or velocity items (e.g., items appearing frequently in orders) may be stored in a pick-to-cart area **302** and be available for immediate picking, and relatively moderate and/or low-volume and/or velocity items may be stored in higher-density storage area **304** on modular storage units **602** which may be retrieved by MSF AGVs **114** for an upcoming pick.

The layout depicted in FIG. **3**A includes various areas: an induction area **308**, a pick-to-cart area **302**, a pick-cell area **310**, a pick-cell staging area **312**, a high-density storage area **304**, a finalizing area **314**, and an elevator for multi-level access (not shown). In some cases the layout may include multiple levels of mezzanine with one or more of the different zones/areas. In some implementation, cart AGVs **116** are staged in the induction area **308** and are set up for picking sessions. In some embodiments, cartons are assembled, labeled with unique scannable visual identifiers to associate them with specific orders, and are placed on the supports (e.g., cart shelves) of the cart AGVs **116** in the induction area **308**.

The pick-to-cart area **302** is configured for high-velocity and/or volume items and advantageously reduces capital associated to handle this type of item class. Inventory may be stored in high-volume storage in cartons or pallets, for example. High velocity items may be divided into pick zones, each zone may include a plurality of bays (e.g., 4, 5, 6+), which may be balanced by the SKU routing engine based on demand by the SKU routing engine. Cart AGVs **116** may be scheduled by the AGV management engine to autonomously visit these zones, and pickers accompanying the cart AGVs **116** may be guided by the picking hardware (e.g., pick-to-voice and/or pick-to-light) controlled by the picking system **108**. In an example, a cart AGV **116** is instructed by the AGV management system to stop directly in front of a bay location. The cart AGV **116** may self-locate using a guidance system. For example, the guidance system may include guidance system locators, such as guide tape (magnetic, colored, etc.), laser target navigation, inertial navigation, vision guidance, geolocation, QR codes on the floor of the distribution facility, RFID (radio frequency identification) tags, beacons, etc., that can be used to locate and navigate AGVs in the distribution facility. Further, the AGVs may include guidance system components configured to read the guidance system locators, such as a QR code reader, wireless radio, etc.

After the picker picks the item and confirms the pick with the picking hardware, the cart AGV **116** autonomously moves to the next sequential bay until the picks are complete. As shown in FIG. **3**A, a cart AGV **116** has the capability to bypass zones, bays, shelves, etc., without picks. Each zone can have dedicated cart AGV **116** accumulation before the zone to reduce cycle time.

The picking station area may include pick-cell stations **316***a*, **316***b*, and **316***c* situated along primary path(s) via which the cart AGVs **116** are routed. In FIG. **3**A, the pick-cell stations **316** are situated opposing a portion of the pick-to-cart area **302** and the cart AGVs **116** may be routed to visit one or more of these pick-cell stations **316** depending on the items that need to be picked and placed in the cartons of these cart AGVs **116**. In the case that in given cart AGV **116** does not require any items from the picking station area, it may bypass it entirely and proceed to the finalizing area **314**.

In some embodiments, for a given picking session, the AGV management engine may establish a single line picking configuration in which the picker and the cart travel through an inventory pick path along a single line until the picks are fulfilled. In further embodiments, based on demand, a fast moving area may be established by the AGV management engine that includes multiple routes: a higher speed line that includes single line picking for low-demand items and another area for high demand items. This combination can advantageously balance daily labor.

The layout may also include a replenishment area **318** in which modular storage units **602** are replenished with items. For instance, item inventory in a given modular storage unit **602** may be replenished by a MSF AGV **114** that picks the modular storage unit **602** from static shelves and transports them to the replenishment area **318** where a case may be opened and items from the case placed directly into the modular storage units **602**. One or more different items can be placed in a given modular storage unit **602**. In some cases the modular storage unit **602** may be replenished while the container is in the static shelf. Having multiple options (manual or AGV) for replenishment has more flexibility to adjust to resource allocation and schedule. Additionally or alternatively, the MSF AGV **114** can swap out the modular storage unit **602** with another containing the same SKUs which has been prepared ahead of time and staged for that purpose.

In some implementations, the AGV management engine may instruct MSF AGVs **114** to replenish and distribute modular storage units **602** in different locations of the high-density storage area **304** based on order history. In these implementations, items with high order frequency orders may be distributed in more locations than items with lower order frequency. The WES **102** may maintain a moving minimum based on order quantity minimizing the need to use inventory from two locations to fulfill an order, and the AGV management engine may schedule the AGVs accordingly.

The modular storage units **602** storing items may be moved by MSF AGVs **114** from high-density storage area **304** into a staging area **312** and staged for movement into a pick-cell station for an upcoming pick. In some embodiments, the storage units of faster-moving items may be moved directed to a pick cell **382** in a given pick-cell station **316**.

In further embodiments, the AGV management engine may instruct a MSF AGV **114** to transfer a modular storage unit **602** between cells of a pick-cell station **316**, or between pick-cell stations **316** (e.g., **316***a* and **316***b*) without having to expend the time to return the modular storage unit **602** to the high-density storage area **304**.

FIG. **3**A also illustrates example paths of AGVs through the distribution facility. The paths are represented by dotted lines, cart AGVs **116** are represented by ovals, and MSF AGVs **114***a* . . . **114***d* are represented by diamonds.

Example cart AGV paths are illustrated in FIG. **3**A, for example, a cart AGV **116** may navigate from an induction area **308**, on a path through the pick-to-cart area **302**, and then to one or more pick-cell stations **316**. Once the picks for the cart AGV **116** have been completed, it may navigate to a finalizing area **314** where cartons are prepared for shipment, for example. Once the cartons have been removed from the cart AGV **116**, the cart AGV **116** may return to the induction area **308** to start through the process again.

Example MSF AGV paths are also illustrated in FIG. **3**A, for example, an MSF AGV **114***a* may transport a modular storage unit E from a first pick-cell station **316***a* to a replenishment area **318** for replenishment. An MSF AGV **114***b* may retrieve a first modular storage unit A from a first location, navigate to a second location, retrieve a second modular storage unit B, and transport both the first and second modular storage units A and B to a pick-cell station **316***b*. An MSF AGV **114***c* may retrieve a modular storage unit C from a first pick-cell station **316***a* and transport it to a second pick-cell station **316***b*. An MSF AGV **114***d* may retrieve a modular storage unit D and transport it back to the high-density storage area **304**. It should be understood that these paths and implementations are provided as examples and that other combinations are possible and contemplated herein. For example, one or more MSF AGVs **114** may perform some or all of the paths illustrated as well as others not illustrated in FIG. **3**A. Further, as described elsewhere herein, the automation of the MSF AGV **114** may be performed in synchronization with other actions (e.g., automation of cart AGVs **116**, picking sessions or windows, movement of other AGVs or pickers, etc.) in the hybrid modular storage fetching system.

FIG. **3**B is an illustration of an example pick-cell station **316**. Each pick-cell station **316** may include one or more pick cells **384**. The pick cells **382** are a temporary storage mediums (e.g., shelves, bays, etc.) for the modular storage units **602** (e.g., mini pallets, totes, modular storage racks, etc.) and modular storage units **602** are storage containers that can be picked up or tugged and transported by a MSF AGV **114**. In some cases the pick-cell station **316** may include an output device, such as a pick-to-light frame, for carts, that matches the locations of the cartons in the cart and/or a pick-to-light frame **384** for the pick cells **382** to indicate the locations of modular storage units **602** to use for a particular pick. For instance, a pick-cell station **316** may include an output device configured to provide picking instructions to a picker, the picking instructions indicating to the picker which of the items in the modular storage units **602** to place in a carton held on the carton holder of the cart AGV **116**.

One or multiple of the pick cells **382** may be organized into a staging area **312** around a picker in a pick-cell station **316**, so that modular storage units **602** can be easily accessed by the picker. In some implementations, an MSF AGV **114** may be configured to stage the modular storage units **602** at the staging area **312**. For instance, an MSF AGV **114** may approach from the rear of a pick cell **382** and stage (e.g., place, deliver, etc.) a modular storage unit **602** on the pick cell **382**. In some implementations, a modular storage unit **602** may be associated by the picking system **108** with a particular location in the staging area **312** to more precisely direct a picker to the location of the modular storage unit **602** (e.g., using a pick-to-light or other output system).

In some implementations, a pick cell **382** may be a device that is mobile and can be transported by an AGV. A mobile pick cell **382** can be preconfigured with modular storage units **602** prior to picking and then transported to the station.

At a given pick-cell station **316**, a cart AGV **116** may arrive and situate itself on one side of the station with the cartons facing the picker. On the other sides of the station are pick cells **382** in which modular storage units **602** situated and from which the picker may select items to fulfill the orders associated with the cartons. The modular storage units **602** may contain one or more items, types of items, etc.

FIGS. **4**A-**4**D are example methods for fulfilling an order in a hybrid modular storage fetching system. FIG. **4**A is a flowchart of an example method for receiving and routing order data **126**. At **402**, the WES **102** may receive an order including items for distribution/fulfillment. The order may be reflected in order data **126** having a unique identification code (e.g., unique product codes, stock keeping units, etc.) for an item and a quantity associated with that item. The order may be assigned a carton (e.g., of a particular size, dimension, etc.) for picking and/or shipping or, in some instances, split into multiple cartons.

At **404**, the WES **102** may analyze the order to determine whether the order includes items in pick-to-cart **302** and/or high-density storage areas **304**. For example, a unique identification code of the items in the order may be matched against information in the data store **120** to evaluate the location (e.g., the particular zone, bay, shelf, modular storage unit **602**, etc.) and quantity of the item in the inventory of the distribution facility.

At **406**, the WES **102** may generate a picking schedule including pick-to-cart, MSF, and/or pick-cell routing, as described above. The generated picking schedule may indicate timing, a particular cart AGV **116** to retrieve pick-to-cart items, a particular MSF AGV **114** to retrieve items in high-density storage, and a particular pick-cell station **316** in which the items from each zone may be combined in a carton. In some implementations, the picking schedule may also indicate an induction station, finalizing area **314**, particular path through the distribution facility, particular pickers or operators assigned to the orders, etc.

At **408**, the dispatching system **106** may transmit a signal identifying pick-to-cart items, item locations, and, in some implementations, identification of a designated pick-cell station **316** and time window for the items to be at the designated pick-cell station **316**, to a cart AGV **116**. It should be noted that other information, such as routing directions, priority, traffic of other AGVs, etc., may also be provided to the cart AGV **116** and/or a computing device of picker(s) associated with the cart AGV **116** to refine the routing and autonomous navigation of the cart AGV **116**.

At **410**, the dispatching system **106** may transmit a signal identifying high-density items, corresponding modular storage units **602**, locations of the corresponding modular storage units **602**, etc., to one or more MSF AGVs **114** (e.g., multiple MSF AGVs **114** may be employed to distribute the work of modular storage unit **602** transport). Other information such as identification of a designated pick-cell station **316** and time window for the items to be at the designated pick-cell station **316**, routing directions, priority, traffic of other AGVs, modular storage unit **602** dimensions, etc., may also be transmitted in the signal to the MSF AGV(s) **114**.

FIG. **4**B is a flowchart of an example method for picking pick-to-cart items using a cart AGV **116**. At **422**, the WES **102** may assign items to carton(s) and associate the cartons with a cart in the database, and at **424**, the dispatch system **106** may dispatch a cart AGV **116** with the cart to a pick-to-cart area **302**, for example, as described above.

At **426**, the cart AGV **116** may navigate to a bay (e.g., a shelving bay) where a pick-to-cart item is stored. The cart AGV **116** may stop adjacent (e.g., in front of) to the location where the item is stored.

At **428**, the picking system **108** may output an instruction to an output device of a picker identifying the item and quantity to be picked at that location. In some implementations, the picking system **108** may coordinate lights or screens on the cart indicating into which carton an item is to be placed and/or lights on a shelving bay/location of the item in the pick-to-cart area **302** indicating the storage location of the item. Other systems, such as audio (e.g., pick-to-voice), a mobile computing device indicating the location of the item, etc., are possible.

At **430**, the picking system **108** and/or cart AGV **116** may determine whether there are additional items in the pick-to-cart area **302** assigned to the cart and, in response to determining that there is an additional item, may return to **426** to navigate to the next location of an item. In some implementations, the order of locations visited by the cart AGV **116** is based on a picking list configured to order the picking according to a designated path through the pick-to-cart area **302**. In some implementations, the output, at **428**, may indicate that an item at a given location is to be picked into multiple cartons (e.g., which cartons may correspond to separate orders) on the cart.

At **432**, in response to a negative determination at **403**, the picking system **108** may determine whether there are items in the high-density storage area **304** also assigned to one or more cartons transported by the cart AGV **116** (and/or whether the cart is scheduled to be delivered to a pick-cell station **316**). If there are no items to be added to the cartons from the high-density storage area **304** (or if, for example, these items are to be added at the finalizing area **314**), the cart AGV **116** may autonomously navigate to a finalizing area **314**. If, however, there are additional items to be added to one or more of the cartons transported by the cart AGV

116 at a pick-cell station 316, the cart AGV 116 may autonomously navigate to an assigned pick-cell station 316 to receive those items. This may be done according to (e.g., at a time window set by) a picking schedule, in coordination with an availability at the pick-cell station 316, and/or in coordination with one or more MSF AGVs 114 delivering items to the assigned pick-cell station 316 to be picked into cartons on the cart AGV 116.

FIG. 4C is a flowchart of an example method for retrieving items in modular storage units 602 from a high-density storage area 304 using an MSF AGV 114. The method depicted in FIG. 4C may be executed in coordination with the method depicted in 4B, for example, as described elsewhere herein.

At 442, the WES 102 may identify a location of a first modular storage unit 602 having an appropriate quantity of first items in response to receiving a signal to retrieve those items from high-density storage (or another current location of a modular storage unit 602, such as a pick-cell station 316, replenishment area 318, etc.). As described above, the quantity of particular items stored in a modular storage unit 602 and the current location (and, in some instances, schedule of future locations) of the modular storage unit 602 are stored in the data store 120. In some implementations, a particular carton, order, or plurality of orders assigned to a cart may require multiple of a particular item. The WES 102 may verify that a sufficient quantity of the item is located in a particular modular storage unit 602 prior to signaling an MSF AGV 114 to retrieve the particular modular storage unit 602. If a particular modular storage unit 602 does not have a sufficient quantity of an item to fill all designated cartons, the MSF AGV 114 may retrieve a different modular storage unit 602 (e.g., having a sufficient quantity of the item), multiple modular storage units 602, or may send an error for a replenishment system/area, a human operator, or other system to remedy the error.

At 444, the WES 102 may identify a location of second modular storage unit(s) 602 having appropriate quantities of second item(s). A set of cartons transported by a cart AGV 116 may include any number of different items to be retrieved from high-density storage by an MSF AGV 114.

At 446, the MSF AGV(s) 114 (e.g., multiple MSF AGVs 114 may be used) may autonomously navigate to a location of a first modular storage unit 602 in a high density storage area, and at 448, the MSF AGV 114 may retrieve the first modular storage unit 602 (e.g., as described in reference to FIGS. 7A-7I).

At 450, an MSF AGV 114 may then autonomously navigate to a location of a second modular storage unit 602 in the high-density storage area 304 and retrieve a second modular storage unit 602. The path of an MSF AGV 114 may be determined to efficiently retrieve each modular storage unit 602. Additionally, the particular modular storage unit 602 (e.g., when multiple modular storage units 602 have a certain item) may be selected based on the most efficient location for the MSF AGV 114 to retrieve and/or proximity to an assigned pick-cell station 316.

At 454, the MSF AGV 114 may autonomously deliver the first modular storage unit 602 to a pick-cell station assigned for the first modular storage unit 602 and, at 456, the MSF AGV 114 may autonomously deliver the second modular storage unit 602 to a pick-cell station 316 assigned for the second modular storage unit 602. In some implementations, the pick-cell station 316 for the first and second modular storage units 602 may be the same pick-cell station 316. In some implementations, the pick-cell stations 316 for the different storage units may be different. For example, an MSF AGV 114 may deliver a first modular storage unit 602 to a first pick-cell station 316 and then autonomously navigate to a second pick-cell station 316 to deliver the second modular storage unit 602.

FIG. 4D is a flowchart of an example method for combining items from different zones of the distribution facility at a pick-cell station 316. Once the cart AGV 116 has transported the cartons to the pick-cell station 316 and the MSF AGV(s) 114 have transported the modular storage units 602 to the pick-cell station 316, the picking system 108 (or another component) may output, at 462, instructions to an output device of a pick-cell station 316 indicating an item to transfer from a modular storage unit 602 to a particular carton. In some implementations, the output device or another computing device may also receive confirmatory input indicating that the item has been placed in a designated carton.

At 464, the picking system 108 determines whether there are additional items from the modular storage units 602 at the pick-cell station 316 assigned to a particular carton. If there are addition items to be picked for a carton, the method may return to 462 for the next item assigned to a carton. If there are no more items to be picked for a particular carton, the picking system 108 may determine, at 466, whether there are additional items from modular storage units 602 assigned to the set of cartons in the cart (e.g., brought by the cart AGV 116 to the particular pick-cell station 316). If there are additional items for additional cartons, the method returns to 462 for those cartons and items and iterates accordingly. It should be noted that the order of the picking, output, confirmation, etc. process, may be changed without departing from the scope of this disclosure.

If the picks for a set of cartons on a cart are complete, at 468, the cart AGV 116 may autonomously navigate to a finalizing area 314, for instance, to ship the cartons.

The picking system 108, WES 102, or another component of the system 100 may move one or more of the modular storage units 602 from the pick-cell station 316. For example, at 470, a picking system 108 may determine whether additional items from a particular modular storage unit 602 are assigned to the pick-cell station 316 in a subsequent picking window (e.g., for a subsequent cart AGV 116 arriving at the pick-cell station 316). If the modular storage unit 602 (e.g., items remaining in the modular storage unit 602) will be used again at the pick-cell station 316, the modular storage unit 602 may be left, at 472, at the pick-cell station 316 for an additional pick window.

At 474, the WES 102 or picking system 108 may determine whether items from a particular modular storage unit 602 are assigned to a different pick-cell station 316 in a subsequent pick window and, if so, at 476, may direct the MSF AGV 114 to retrieve the modular storage unit 602 from the current pick-cell station 316 and deliver it to the different pick-cell station 316.

At 478, the MSF AGV 114 may retrieve one or more modular storage unit(s) 602 from the pick-cell station 316, autonomously navigate to a location in the high-density storage area 304, and store the modular storage unit 602 at that location. The locations at which the modular storage units 602 are stored may be determined based on availability, proximity to a pick-cell area 310, proximity to frequently co-ordered items, frequency with which the items in the modular storage units 602 are retrieved, or any other schema.

In some implementations, if all of a particular item in a modular storage unit 602 have been picked from the modular storage unit **602** (e.g., it is empty), then the MSF AGV **114** may autonomously deliver the modular storage unit **602** to a replenishment area **318**.

FIGS. **5**A and **5**B are illustrations of example cart AGVs **502***a* and **502***b* (e.g., also referred to as **116**). The example cart AGVs may include an automated guided vehicle **502** or robot configured to autonomously transport pick-to-cart items, as described above. The cart AGV **502** may include or be adapted to autonomously transport a carton holder **504***a* or **504***b* (e.g., a cart or shelves) that is adapted to hold cartons (not shown in FIGS. **5**A or **5**B). For example, a cart AGV **502** may push/pull a cart (e.g., a carton holder **504**). In some implementations, a carton may be a box placed on a shelf of the carton holder **504**.

FIGS. **6**A-**6**B are illustrations of example modular storage units **602***a* and **602***b*. In some embodiments, the modular storage units **602** are containers or sets of containers that may be moved between storage shelves, pick cells **382**, etc. Modular storage units **602** may have various heights and widths (e.g., 2 to 24 inches high, and 1, 2, or 4 feet wide) and depths equal to the depths of shelving units (e.g., 18 to 24 inches). For example, the modular storage units **602** may be sized and configured to hold items commonly stocked in a fulfillment or distribution facility while also fitting onto standard shelves. A modular storage unit **602** may include a holding structure (e.g., a pallet as in **6**A or a container as in **6**B) adapted to hold items. The holding structure may be adapted to interface with a retrieval mechanism (e.g., a fork) of an MSF AGV **114**.

As illustrated in FIG. **6**A, a modular storage unit **602***a* may comprise a pallet or tote, which may be a holding container to support items designed to be picked up by an MSF AGV **114** using its retrieval mechanism. For example, a modular storage unit **602***a* may include a pallet and a holding structure that supports items designed to be picked up by an AGV with forks. In some implementations, a pallet may be stackable. In some implementations, a pallet may be attachable to a container to form a modular storage unit **602** such as the example depicted in FIG. **6**B.

FIG. **6**B illustrates another example modular storage unit **602***b*. As illustrated, a modular storage unit may include sides **604** and one or more divisions **608** dividing the modular storage unit **602***b* into multiple compartments. Further, in some implementations, a modular storage unit **602***b* may include a door **610**, which may be opened and closed by a picker to provide easy access to items stored in the compartments. In some implementations, an MSF AGV **114** may automatically position the door **610** toward the center of a pick-cell station **316** to allow access by a picker.

FIGS. **7**A-**7**I are illustrations of example MSF AGVs **702***a*, **702***b*, **702***c*, **702***d*, and **702***e* (also referred to as **114** herein). FIGS. **7**A and **7**B illustrate a first example MSF AGV **702***a*. In some implementations, the MSF AGV **702***a* may have the capability to reach and retrieve different size of modular storage units **602** (e.g., pallets, totes, etc.) from different levels of static shelves. The MSF AGV **702***a* may be equipped with retrieval mechanism **704** adapted to interface with the holding structure of a modular storage unit **602** to retrieve a given modular storage unit **602** from a modular storage unit support structure **722** (e.g., a shelving unit, pick cell **382**, or other support structure) and, in some implementations, place the modular storage unit **602** in a modular storage unit holder **706** of the MSF AGV **702**. For instance, the retrieval mechanism **704** may be adapted to extract the modular storage unit **602** from a shelving unit (e.g., **722**) and place of the modular storage unit **602** into a new location (e.g., a pick cell).

The retrieval mechanism **704** may include an elevator mechanism **708** to lift the modular storage unit **602** to one or more levels of the modular storage unit holder **706**. The modular storage unit holder **706** may include one or more bays, shelves, or containers configured to receive modular storage units **602** in a single or various sizes. The retrieval mechanism **704** may be adapted to place a given modular storage unit **602** in any of the plurality of bays.

In some implementations, the retrieval mechanism of a MSF AGV **702** may include forks **712**, such as those depicted in FIGS. **7**C-**7**I, which are designed to engage with a corresponding support structure of the modular storage unit **602** (e.g., a bottom surface, preformed indentation(s), preconfigured channel(s), other structures or formations, etc.). Forks **712** can be made of any material, such as plastic or metal.

As illustrated in FIG. **7**C-**7**F, the forks **712** may be attached to an elevator mechanism **708** and may be retractable, so the forks **712** may be placed at any desired height and maneuvered underneath and to lift the modular storage unit **602** from a shelving unit (e.g., **722**) during extraction.

As illustrated in FIGS. **7**D, **7**G-**7**I, the retrieval mechanism of the MSF AGV may include a fork **712** coupled with the MSF AGV **702** and configured to lift the given modular storage unit **602** and remove the given modular storage unit **602** from the modular unit storage structure **722**.

As illustrated in FIG. **7**G-**7**I, the forks **712** may be attached to a robotic arm **716***a* or **716***b* and may be pivotable to extend underneath a modular storage unit **602** in order to lift the modular storage unit **602**.

It should be noted that the components described herein may be further delineated or changed without departing from the techniques described herein. For example, the processes described throughout this disclosure may be performed by fewer, additional, or different components.

It should be understood that the methods described herein are provided by way of example, and that variations and combinations of these methods, as well as other methods, are contemplated. For example, in some embodiments, at least a portion of one or more of the methods represent various segments of one or more larger methods and may be concatenated or various steps of these methods may be combined to produce other methods which are encompassed by the present disclosure. Additionally, it should be understood that various operations in the methods are iterative, and thus repeated as many times as necessary generate the results described herein. Further the ordering of the operations in the methods is provided by way of example and it should be understood that various operations may occur earlier and/or later in the method without departing from the scope thereof.

In the above description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it should be understood that the technology described herein can be practiced without these specific details in various cases. Further, various systems, devices, and structures are shown in block diagram form in order to avoid obscuring the description. For instance, various embodiments are described as having particular hardware, software, and user interfaces. However, the present disclosure applies to any type of computing device that can receive data and commands, and to any peripheral devices providing services.

In some instances, various embodiments may be presented herein in terms of algorithms and symbolic representations of operations on data bits within a computer memory. An algorithm is here, and generally, conceived to be a self-consistent set of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout this disclosure, discussions utilizing terms such as "processing," "computing," "calculating," "determining," "displaying," or the like, refer to the action and methods of a computer system that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

A data processing system suitable for storing and/or executing program code, such as the computing system and/or devices discussed herein, may include at least one processor coupled directly or indirectly to memory elements through a system bus. The memory elements can include local memory employed during actual execution of the program code, bulk storage, and cache memories that provide temporary storage of at least some program code in order to reduce the number of times code must be retrieved from bulk storage during execution. Input or I/O devices can be coupled to the system either directly or through intervening I/O controllers. The data processing system may include an apparatus may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer.

The foregoing description has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the specification to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the disclosure be limited not by this detailed description, but rather by the claims of this application. As will be understood by those familiar with the art, the specification may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Likewise, the particular naming and division of the modules, routines, features, attributes, methodologies and other aspects may not be mandatory or significant, and the mechanisms that implement the specification or its features may have different names, divisions, and/or formats.

Furthermore, the modules, routines, features, attributes, methodologies and other aspects of the disclosure can be implemented as software, hardware, firmware, or any combination of the foregoing. The technology can also take the form of a computer program product accessible from a computer-usable or computer-readable medium providing program code for use by or in connection with a computer or any instruction execution system. Wherever a component, an example of which is a module or engine, of the specification is implemented as software, the component can be implemented as a standalone program, as part of a larger program, as a plurality of separate programs, as a statically or dynamically linked library, as a kernel loadable module, as firmware, as resident software, as microcode, as a device driver, and/or in every and any other way known now or in the future. Additionally, the disclosure is in no way limited to implementation in any specific programming language, or for any specific operating system or environment. Accordingly, the disclosure is intended to be illustrative, but not limiting, of the scope of the subject matter set forth in the following claims.

What is claimed is:

1. A method comprising:

generating, by one or more computing devices, a picking schedule including pick-to-cart routing based on order data, the picking schedule indicating when to deliver one or more first items to a pick-cell station, the order data including one or more first identification codes representing the one or more first items located in a pick-to-cart area of a distribution facility, the picking schedule identifying one or more shipping cartons assigned to be transported by a cart automated guided vehicle (AGV) and into which the one or more first items of the order data may be placed;

dispatching, by the one or more computing devices, the cart AGV according to the picking schedule, the cart AGV including a drive unit adapted to provide motive force to the cart AGV and a guidance system adapted to locate the cart AGV in the distribution facility, the cart AGV adapted to autonomously transport the one or more shipping cartons, the one or more shipping cartons adapted to hold items during transportation by the cart AGV and shipment to a shipping address;

autonomously navigating, by the one or more computing devices, the cart AGV through the pick-to-cart area according to the pick-to-cart routing to allow picking of the one or more first items located in the pick-to-cart area; and

autonomously navigating, by the one or more computing devices, the cart AGV to the pick-cell station according to the pick-to-cart routing.

2. The method of claim **1**, wherein

the order data includes one or more second identification codes representing one or more second items located in a high-density storage area of the distribution facility,

the picking schedule includes a modular storage fetching (MSF) routing, and

the method further includes

dispatching, by the one or more computing devices, an MSF AGV according to the picking schedule, the MSF AGV including a drive unit adapted to provide motive force to the MSF AGV, a guidance system adapted to locate the MSF AGV in the distribution facility, and a modular storage unit holder adapted to hold one or more modular storage units, the MSF AGV adapted to autonomously retrieve the one or more modular storage units from the high-density storage area and transport the one or more modular storage units to the pick-cell station,

autonomously navigating, by the one or more computing devices, the MSF AGV to a location of the one or more modular storage units in the high-density storage area, the one or more modular storage units containing the one or more second items, and

autonomously retrieving, by the MSF AGV, the one or more modular storage units from the high-density storage area.

3. The method of claim **2**, further comprising autonomously navigating, by the one or more computing devices, the MSF AGV from the location of the one or more modular storage units in the high-density storage area to the pick-cell station according to the MSF routing.

4. The method of claim 2, wherein

autonomously navigating the MSF AGV to the location of the one or more modular storage units in the high-density storage area includes

autonomously navigating the MSF AGV to a first location of a first modular storage unit in the high-density storage area, the first modular storage unit containing a first particular item of the one or more second items, and

autonomously navigating the MSF AGV from the first location of the first modular storage unit to a second location of a second modular storage unit, the second modular storage unit containing a second particular item of the one or more second items, and

autonomously retrieving, by the MSF AGV, the one or more modular storage units includes

autonomously retrieving, by the MSF AGV, the first modular storage unit from the first location of the first modular storage unit in the high-density storage area, and

autonomously retrieving, by the MSF AGV, the second modular storage unit from the second location of the second modular storage unit.

5. The method of claim 4, wherein the second location of the second modular storage unit is a second pick-cell station.

6. The method of claim 4, wherein the second location of the second modular storage unit is a different location of the high-density storage area than the first location of the first modular storage unit.

7. The method of claim 2, further comprising

autonomously navigating the MSF AGV from the location of the one or more modular storage units in the high-density storage area to the pick-cell station; and

autonomously delivering, by the MSF AGV, a first modular storage unit to the pick-cell station.

8. The method of claim 2, wherein the MSF AGV is further adapted to stage the one or more modular storage units at a staging area of the pick-cell station.

9. The method of claim 2, wherein the MSF AGV is adapted to retrieve multiple sizes of modular storage units.

10. The method of claim 2, wherein

the one or more modular storage units include a holding structure adapted to hold items, the holding structure adapted to interface with a retrieval mechanism of the MSF AGV, and

the MSF AGV includes the retrieval mechanism adapted to interface with the holding structure to retrieve a given modular storage unit from a modular storage unit support structure and place the given modular storage unit in the modular storage unit holder.

11. The method of claim 10, wherein

the retrieval mechanism of the MSF AGV includes a fork coupled with the MSF AGV and configured to lift the given modular storage unit and remove the given modular storage unit from the modular storage unit support structure, and

the modular storage unit support structure includes a shelf.

12. The method of claim 10, wherein

the modular storage unit holder of the MSF AGV is adapted to hold a plurality of modular storage units.

13. The method of claim 12, wherein

the modular storage unit holder of the MSF AGV includes a plurality of bays, each bay adapted to hold a modular storage unit, and

the retrieval mechanism is adapted to place the given modular storage unit in any of the plurality of bays.

14. The method of claim 2, wherein the pick-cell station includes an output device configured to provide picking instructions to a picker, the picking instructions indicating to the picker which of the one or more second items from the one or more modular storage units to place in a given shipping carton held on the cart AGV.

15. A method comprising:

dispatching, by one or more computing devices, a cart automated guided vehicle (AGV) according to a picking schedule that includes when to deliver one or more first items to a pick-cell station, the cart AGV including a drive unit adapted to provide motive force to the cart AGV and a guidance system adapted to locate the cart AGV in a distribution facility, the cart AGV adapted to autonomously transport one or more shipping cartons, the one or more shipping cartons adapted to hold one or more items during transportation by the cart AGV and shipment to a shipping address, the picking schedule identifying the one or more shipping cartons assigned to be transported by the cart AGV and into which the one or more first items may be placed;

dispatching, by the one or more computing devices, a modular storage fetching (MSF) AGV according to the picking schedule, the MSF AGV including a drive unit adapted to provide motive force to the MSF AGV and a guidance system adapted to locate the MSF AGV in the distribution facility, the MSF AGV adapted to hold a plurality of modular storage units and retrieve the plurality of modular storage units from a high-density storage area and transport the plurality of modular storage units to a pick-cell station;

autonomously navigating, by the one or more computing devices, the cart AGV through a pick-to-cart area according to the picking schedule to retrieve a first item located in the pick-to-cart area;

autonomously navigating, by the one or more computing devices, the cart AGV to the pick-cell station according to the picking schedule;

autonomously navigating the MSF AGV to a first location of a first modular storage unit in the high-density storage area, the first modular storage unit containing a second item;

autonomously retrieving, by the MSF AGV, the first modular storage unit from the first location;

autonomously navigating the MSF AGV from the first location to a second location of a second modular storage unit, the second modular storage unit containing a third item;

autonomously retrieving, by the MSF AGV, the second modular storage unit from the second location; and

autonomously delivering, by the MSF AGV, the first modular storage unit and the second modular storage unit to the pick-cell station.

16. A system comprising:

a first processor adapted to generate a picking schedule, the picking schedule indicating when to deliver one or more first items to a pick-cell station and including a pick-to-cart routing based on order data, the order data including one or more first identification codes representing the one or more first items located in a pick-to-cart area of a distribution facility, and to transmit a signal including the picking schedule to a second processor dispatching system, the picking schedule identifying one or more shipping cartons assigned to be transported by a cart automated guided vehicle (AGV) and into which the one or more first items of the order data may be placed;

the second processor adapted to dispatch the cart AGV according to the picking schedule, the cart AGV including a drive unit adapted to provide motive force to the cart AGV and a guidance system adapted to locate the cart AGV in the distribution facility, the cart AGV adapted to autonomously transport the one or more shipping cartons, the one or more shipping cartons adapted to hold one or more items during transportation by the cart AGV and shipment to a shipping address; and

the cart AGV adapted to autonomously navigate through the pick-to-cart area according to the pick-to-cart routing to retrieve the one or more first items located in the pick-to-cart area, and autonomously navigate to a pick-cell station according to the pick-to-cart routing.

17. The system of claim **16** further comprising a modular storage fetching (MSF) AGV including a drive unit adapted to provide motive force to the MSF AGV, a guidance system adapted to locate the MSF AGV in the distribution facility, and a modular storage unit holder adapted to hold one or more modular storage units, the MSF AGV adapted to autonomously retrieve the one or more modular storage units from a high-density storage area and transport the one or more modular storage units to the pick-cell station.

18. The system of claim **17** wherein the MSF AGV is further configured to

autonomously navigate to a location of the one or more modular storage units in the high-density storage area, the one or more modular storage units containing a second item, and autonomously retrieve the one or more modular storage units from the high-density storage area.

19. The system of claim **18** wherein the MSF AGV is further configured to autonomously navigate from the location of the one or more modular storage units in the high-density storage area to the pick-cell station, and autonomously deliver the one or more modular storage units to the pick-cell station.

20. The system of claim **17** wherein the second processor is further configured to dispatch the MSF AGV according to the picking schedule.

* * * * *